CANADA
DEPARTMENT OF FORESTRY
AND RURAL DEVELOPMENT

THE CANADA LAND INVENTORY

ARDA

THE CLIMATES OF CANADA FOR AGRICULTURE

The Canada Land Inventory

Report No. 3

1966

Published under the authority of
THE HONOURABLE MAURICE SAUVÉ, P.C., M.P.,
Minister of Forestry and Rural Development
Ottawa, 1966

For more detailed information about the Canada Land Inventory and for future special publications as they become available, please address correspondence to:

Canada Land Inventory,
ARDA,
Department of Forestry
and Rural Development,
Ottawa, Canada.

ROGER DUHAMEL, F.R.S.C., QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1966

Cat. No. Fo63-3/1966

THE
CANADA LAND
INVENTORY

Report No. 3 - 1966

THE CLIMATES
OF CANADA
FOR AGRICULTURE

Prepared by
L. J. Chapman and D. M. Brown,
Department of Physiography,
Ontario Research Foundation,
Toronto 5, Ontario.

Under contract with the
Agricultural and Rural
Development Act Administration

DEPARTMENT OF FORESTRY
AND RURAL DEVELOPMENT,
CANADA

CONTENTS

	Page
LIST OF FIGURES	v
ACKNOWLEDGEMENTS	vi
THE CLIMATES OF CANADA FOR AGRICULTURE	1
SEASONAL WEATHER CONDITIONS	1
LENGTH OF DAY	4
TEMPERATURES AND THE GROWING SEASON	4
July and January Mean Temperatures	5
Winter Extremes	6
Growing Season	6
Degree-days Above 42°F	6
The Frost-free Period	8
Corn Heat Units	9
MOISTURE	10
Average Annual Precipitation	10
Average May to September Precipitation	10
Potential Evapotranspiration	11
Average Annual Water Deficiency	11
Actual Evapotranspiration	12
CLASSIFICATION	13
Temperature Zones	13
Moisture Classes	14
Climatic Regions	15
Table 1. Regional Climates of Southern Canada	17
REFERENCES	24
BIBLIOGRAPHY	24

LIST OF FIGURES

		Page
1.	Diurnal duration of daylight for the year at two latitudes in Canada	4
2.	Mean monthly maximum and minimum temperatures showing annual variation for six weather stations across Canada	5
3.	Mean monthly maximum temperature and hours of bright sunshine received at Medicine Hat, Alberta	5
4.	July mean temperature ... follows page	6
5.	January mean temperature ... follows page	6
6.	Mean annual minimum temperature ... follows page	6
7.	Start of the growing season ... follows page	6
8.	End of the growing season ... follows page	6
9.	Degree-days above 42°F ... follows page	8
10.	Mean spring frost date ... follows page	8
11.	Mean fall frost date ... follows page	8
12.	Mean "frost-free" period ... follows page	8
13.	Corn heat units ... follows page	10
14.	Mean monthly precipitation ... follows page	10
15.	Average annual precipitation ... follows page	10
16.	Average May to September precipitation ... follows page	10
17.	Potential evapotranspiration ... follows page	10
18.	Relation between water deficiency computed from monthly weather data for each year and from 1921-1950 normals	11
19.	Average annual water deficiency ... follows page	12
20.	Average annual actual evapotranspiration ... follows page	12
21.	Relation between average annual hay yields at experiment stations across Canada and average actual evapotranspiration	13
22.	Temperature zones ... follows page	14
23.	Moisture classes ... follows page	14
24.	Climatic regions for agriculture ... follows page	16

ACKNOWLEDGEMENTS

This study was initiated and supported by the Agricultural and Rural Development Act administration. In preparing this publication, it was necessary to use published or readily available climatic data. All climatic data used for this report were obtained from the Meteorological Branch, Canada Department of Transport, Toronto. Messrs. C. C. Boughner and M. K. Thomas and their staff in the Climatology Division were most co-operative in making unpublished records available. A general advisory committee comprising Messrs. R. C. Hodges, L. E. Pratt, Geo. W. Robertson, M. K. Thomas and Dr. P. O. Ripley contributed valuable encouragement and support. The advice received from many soil and crop specialists, meteorologists and geographers in the provinces across Canada has been invaluable.

THE CANADA LAND INVENTORY

This report, describing an analysis and classification of climate for agriculture, is one of a series of reports to be published on the methods and results of the Canada Land Inventory. The Objectives, Scope and Organization of the Canada Land Inventory are described in Report No. 1 (available from the Department of Forestry and Rural Development).

The Canada Land Inventory is a comprehensive survey of land capability and use for various purposes. It includes assessments of land capability for agriculture, forestry, recreation and wildlife, information on present land use, and assessments of social and economic factors relative to land use. It is being undertaken as a co-operative federal-provincial program administered under the Agricultural and Rural Development Act (ARDA) of June 1961.

Climatic information is needed to assist in the understanding of land productivity as related to the development of Canada's resources. This report was prepared to offer specific information on climates for this purpose, as well as for federal and provincial ARDA programs.

The analysis is a reconaissance approach for national comparisons and it is realized that it may not satisfy the detailed requirements needed at the regional and provincial levels. It may be necessary to undertake more detailed studies at these levels as conditions warrant.

THE CLIMATES OF CANADA FOR AGRICULTURE

The productivity of land depends on climate as well as soil. Climate dictates what crops may be grown and is mainly responsible for yearly variation in yields. A classification of land in the broad sense of the term must take climate into account. To a considerable extent soil profiles reflect the effects of climate, and soil zones serve in a general way as climatic zones. However, a description of climate is needed for an understanding of the environment. A classification of Canadian lands is now being carried out for the purposes of the Agricultural and Rural Development Act. This account of the climate of the settled parts of Canada is intended to aid in the land classification and it stresses field-crop relationships.

This report is divided into three sections. The first, Temperatures and the Growing Season, describes and explains the weather conditions which prevail during the four seasons in the various parts of the country. Climate is weather in the aggregate and this preliminary section is included to discuss weather regimes before proceeding to the second section, Moisture, in which temperature and moisture maps based on average data tend to obscure the day-by-day variations in weather.

The second section deals with the description of the climate. The description is based on average temperature and moisture data with sixteen maps showing geographic variations. They are supplemented by several charts and graphs.

The third section deals with classification. The procedure followed was to divide the country into temperature zones and moisture classes, then combine them to give climatic regions. This classification relates to field crops because it is in general farming areas rather than special crop areas that ARDA programs are likely to apply.

SEASONAL WEATHER CONDITIONS

Due to the daily weather forecasts on television nearly everyone is now familiar with weather maps and the concept of opposing air masses. There is a general pattern of circulation to the atmosphere in these latitudes which produces changeable weather. Areas of good or bad weather move across North America, not along precise weather tracks, but following a general pattern of movement. The general circulation results from nature's maintenance of the overall heat balance of the earth and its atmosphere. Basically, the fundamentals are quite simple: tropical regions build up an excess of heat because solar radiation is in excess of the terrestrial radiation back to space, while in the polar regions less radiation is received than is lost to space. The equatorial regions do not grow continually hotter and the polar regions continually colder because, periodically, large masses of hot air move north and cold air masses move south to maintain a

heat balance. Thus in southern Canada we may, in any season of the year, suffer from either relatively cold or cool Arctic outbreaks or from surges of mild or hot air from the south. Because of the rotation of the earth these large air masses, usually measuring hundreds of miles across, are not able to move directly north or south, but usually are forced to move in an easterly direction. The wide belt of latitude which covers southern Canada is known as the zone of the "westerlies".

There is a very good analogy between the movement of hot and cold air masses on a continental scale and opposing armies on a battlefield. The term "front", meaning a long, narrow zone of discontinuity between two contrasting air masses, originated from this analogy. High-pressure areas are usually associated with homogeneous air masses and fine weather, while low-pressure areas, usually situated along fronts between air masses with contrasting properties, produce much cloud, precipitation, and usually a wind shift and temperature change. Fronts and low-pressure areas with their associated periods of bad weather, usually move from a westerly quadrant across southern Canada at all times of the year, but such activity is more vigorous in winter than in summer. Most areas in southern Canada are affected by weather from low-pressure areas and a change in air mass every three or four days, but there are wide seasonal variations in the frequency of frontal activity in different parts of the country. In addition, relatively small and local showers or thunderstorms, quite independent of the low-pressure systems, can and do occur over most of Canada, especially in the summer season.

The physical geography of Canada also plays a considerable role in fashioning the weather and climate of the country. The mean position of fronts and storm tracks in the general circulation is determined to a considerable extent by the shape of the continent. The climates of British Columbia and the western Prairie Provinces are considerably influenced by the physical blocking of movements of the lower atmosphere by the Western Cordillera. Hudson Bay, the Great Lakes, and the Gulf of St. Lawrence are responsible for ameliorating the climates inland from their lee shores, and the lack of any outstanding physical features on the Prairies makes this part of the country particularly subject to drastic weather changes.

British Columbia

From west to east British Columbia consists of a chain of rugged islands in the Pacific Ocean, the Coast Range, an interior plateau cut deeply by valleys and with mountainous areas, then the Rocky Mountains. Although the warming effect of the North Pacific Drift on this Canadian coast is less effective than the Gulf Stream on the coast of Europe, it still exerts a major influence. During winter, with a fairly steady succession of low-pressure systems moving in from the Pacific Ocean, the warm, humid air in contact with the coastal slopes produces the cloudiest season of the year for any part of Canada. At the height of the rainy season in December, there is on the average nine inches of precipitation and 23 rainy days at Vancouver Airport. In contrast to the tiresome, drizzly, winter weather the summers (May to September) have frequent long spells of fine, sunny weather as great north Pacific high-pressure cells extend over the coast of British Columbia. On the average there are only six rainy days in July at Victoria. The air is warm but sea breezes in the afternoon usually forestall very high temperatures. Cold nights are also rare in summer due to the marine influence.

The lower Fraser Valley, which accounts for much of the agricultural production in British Columbia, extends 80 miles inland from the coast at Vancouver. This is the largest passage through the Coast Range and its climate changes noticeably with distance from the coast. The inland areas tend to have cooler, less cloudy weather with more snowfalls in winter, and higher temperatures with more rain due to thunderstorms in summer. Sea and land breezes blow up and down the valley and are characteristic of fine days in summer. In spite of occasional falls of snow the lower Fraser Valley usually stays green all winter. The area below Hope is better regarded as part of the littoral belt than of the southern interior valleys.

In the southern interior of British Columbia the mountain ranges and valleys generally run north and south. Currents of air moving eastward from the Pacific thus move across the grain of the country and the westerly slopes receive more precipitation during the year than the easterly slopes and valleys. Storms from the Pacific Ocean affect the interior, in winter particularly, but lose intensity as they move inland. In summer there is considerably more shower and thunderstorm activity in the interior than on the coast. In all the interior of British Columbia the precipitation regime throughout the year is remarkably uniform; for example it averages about an inch a month at Penticton representing the valleys in the south and two inches at Prince George in the north. The summers, particularly in the south are dry. The fairly wide daily range of temperatures and the cool to cold winters and warm summers make this area continental in character rather than maritime.

In this area practically all of the settlement and consequently almost all the weather stations are situated in the valleys. No attempt is made to deal with the climate of the slopes and tops of the mountains. To do this would require concerted study and additional weather records taken over a period of years.

Prairie Provinces

Comprising part of the Central Plains of North America, the Prairie Provinces slope eastward from about 4,000 feet above sea level in the foothills of the Rocky Mountains to under 1,000 feet in Manitoba. These plains extend away to the Arctic Ocean with no east-west mountain ranges to block the southward movement of cold air. Likewise there is no obstacle to prevent warm air from moving northward from the United States. Thus, there are often violent temperature changes. Many of the low-pressure areas which subsequently affect eastern Canada originate in the lee of the continental divide and these systems usually deepen as they move eastward from Alberta across Saskatchewan and Manitoba. Frontal activity is present in all seasons but is usually most pronounced in the spring. Temperature extremes are the widest in Canada, for example the highest and lowest ever recorded at Regina are 110° and —56°F, respectively. Frost penetration into the ground sometimes reaches 10 feet.

Located in the centre of the continent east of the mountains which separate it from the Pacific Ocean the air over the Prairie Provinces is usually too dry to give much precipitation. However, local showers and thunderstorms are fairly frequent during the summer, especially in the eastern Prairies. In June and July the average number of days with measurable precipitation at most stations is 10 or 12 a month, while in April and September the comparable numbers of wet days amount to only six or eight. Hailstorms are fairly common in the open grass-lands, damage to grain crops occurring about once in 12 to 17 years as a general rule. Severe hailstorms are less frequent in park-land and rare in forested regions.

Fortunately for agriculture, precipitation is lightest in winter and heaviest in summer in the Prairie Provinces. This is in direct contrast to the high winter and low summer precipitation regime on the west coast. From the Great Lakes eastward the distribution is fairly even throughout the year.

Two weather phenomena, Chinook winds and blizzards are well known on the Prairies. In the foothills of Alberta, temperatures often increase from below zero to well above freezing in a few hours as warm, dry air subsides in the lee of the mountains. Sometimes these winds rapidly clear the snow blanket off the ground. The frequency of thawing days in winter when the crisp snow turns to slush is highest in southern Alberta and diminishes towards the north and east. Also in winter, prairie blizzards, with bitterly cold temperatures accompanying strong winds and driving snow, often bring outdoor activities to a halt for several days.

In summary, the Prairie Provinces have an extreme continental type of climate with short, warm summers and very cold, long winters. Precipitation is the least during the fall and winter and 40 to 50 per cent of the annual total falls during the three summer months.

Northern Ontario and Northern Quebec

The winter minimum and summer maximum in precipitation become less pronounced eastward from the Prairies but still prevails north of the Great Lakes and into northern Quebec. The latter region is well within the zone of influence of humid air masses from the south and precipitation increases from 20 inches in northwestern Ontario to 40 inches in the Saguenay country of Quebec. The number of days with measurable precipitation each month from June to October runs from 14 to 19 and drizzly, wet harvesting weather is troublesome in the few farming settlements in the clay belts of this region. Fortunately, there are slightly fewer wet days in the spring. Snowfall is much heavier than on the Prairies and since thaws are infrequent, the snow accumulates to depths of 30 inches in the west and 60 inches in the east, on the average. Spring comes later in this area than in the Prairie Provinces where winters are similarly cold.

In summary this region may be classed as humid continental with very cold snowy winters, only moderately warm summers and ample precipitation with a summertime maximum.

Southern Ontario and Southern Quebec

The lower Great Lakes region and St. Lawrence Valley lie on one of the major storm tracks of North America and there is usually a regular procession of high- and low-pressure systems moving over the region from west to east, throughout the year. This activity is, however, greater in winter than in summer. A day or two of mild weather followed by cooler, fine weather, then changing winds and often rain or snow and mild weather, repeated over and over produce a very changeable climate. The precipitation regime is remarkably uniform throughout the year because of the frequency of storms together with thunderstorm and shower activity in the relatively humid warm air during the summer. Periods of either excessively dry or wet weather are not common. Ten or twelve days a month with measurable rainfall is the average at most stations in summer.

Southwestern Ontario is greatly influenced by the Great Lakes especially in winter. Winter temperatures are 5° to 10°F higher in southwestern Ontario than at comparable latitudes and altitudes in midwestern United States, and summer temperatures 5° to 10° cooler. This region is more humid than northern

Ontario and the Prairie Provinces. The lakes also mitigate against late spring and early fall frosts, giving a definite advantage to special fruit and vegetable crops in the areas bordering them.

Atlantic Provinces

Most of the migrant low-pressure areas moving across eastern North America pass over the Atlantic Provinces, and consequently this part of Canada has storms more frequently throughout the year than any other section of the country. Despite the maritime location of this region, the climate is a modified continental type. It is affected by the general easterly movement of air masses from the interior and because of this the mean annual range of temperature on the Nova Scotia coast is almost double that on the Pacific coast. At Halifax, January averages 24° and July 65°F. However, near the coast there are frequent influxes of moist Atlantic air which produce mild spells in winter and cool, foggy periods in the summer. In the spring, frequent northeast winds cooled by the waters of the Labrador current delay the season.

Precipitation is usually ample during the growing season in all parts of the Atlantic Provinces. Most of it is produced by cyclonic storms; thunderstorms in summer are not frequent, occurring on the average 10 or 12 times a year. Usually, precipitation is heaviest in late fall and early winter, except in the northern interior of New Brunswick where a more continental regime exists, in which relatively low winter and high summer precipitation prevails. Generally these provinces are rather cloudy with sunshine hours highest in August and lowest in December.

Mention must also be made of the fogs along the coasts where up to ninety days a year are foggy. The Northumberland Strait area is exceptional in being fairly free of fogs with only ten foggy days a year. Usually fogs occur in the morning, clearing up before noon. Along the south coast of Nova Scotia the fogs are most frequent in summer whereas farther north the maximum occurs in late spring and early summer. The Annapolis Valley has only about ten foggy days a year, much less than the Bay of Fundy shore. The North Mountain, which lies between the two, quite effectively serves as a barrier, although often the fog may be seen piled along its crest, wisps of it occasionally spilling over and dissipating on the south slope.

In summary, this region has a modified continental-type climate despite its maritime location. It has changeable weather due to the passage of numerous storms as they leave the continent. Winters are cold, raw and quite snowy. Springs are late and short, summers cool and rather cloudy especially along the coast. The coast is frequently foggy. Moisture is nearly always ample during the growing season and often excessive in spring and fall.

LENGTH OF DAY

It is well known that daylength affects the growth and development of plants. The unusually rapid growth of hay and pasture during the long days in northerly latitudes and similarly the rapid development of wheat are often mentioned (3, 4, 16). As a convenient reference, a graph of the number of hours of daylight throughout the year is given for latitudes 42° and 56°N in Figure 1. These two latitudes represent the southern and northern limits of commercial agriculture in Canada.

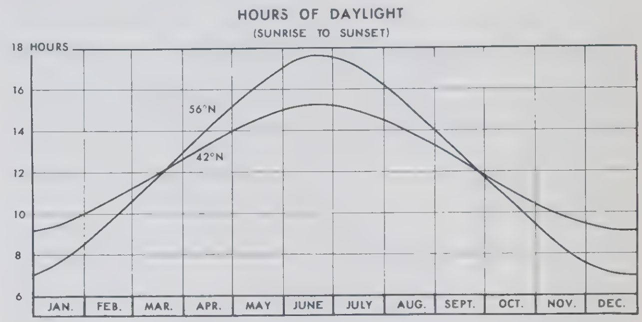


FIGURE 1: Diurnal duration of daylight for the year at two latitudes in Canada.

Latitude 42°N runs through Essex County in southwestern Ontario. It also passes just north of the cities of Chicago, U.S.A. and Rome, Italy, and through the northern ends of the states of California, Utah, Connecticut and Rhode Island. Latitude 56°N runs through the Peace River district in British Columbia and Alberta and, for comparison, near Edinburgh, Scotland and Copenhagen, Denmark.

TEMPERATURES & THE GROWING SEASON

In this report the 1921-1950 temperature normals published by the Meteorological Branch were used to plot annual graphs from the mean monthly temperatures. Such curves for about 640 weather stations across Canada were used to derive the dates of the start and end of the growing season and degree-days above 42°F. When the 1931-1960 normals became available more recently they included monthly mean maximum and minimum temperatures. Curves based on these records for nearly 700 stations were drawn and used in deriving frost dates and "corn heat units". A few representative curves are shown in Figure 2. The shape of the curves and the range between maximum and minimum temperatures tell a good deal about the climate of any location.

Incidentally, a peculiarity of the maximum temperature curves for stations especially in Alberta and

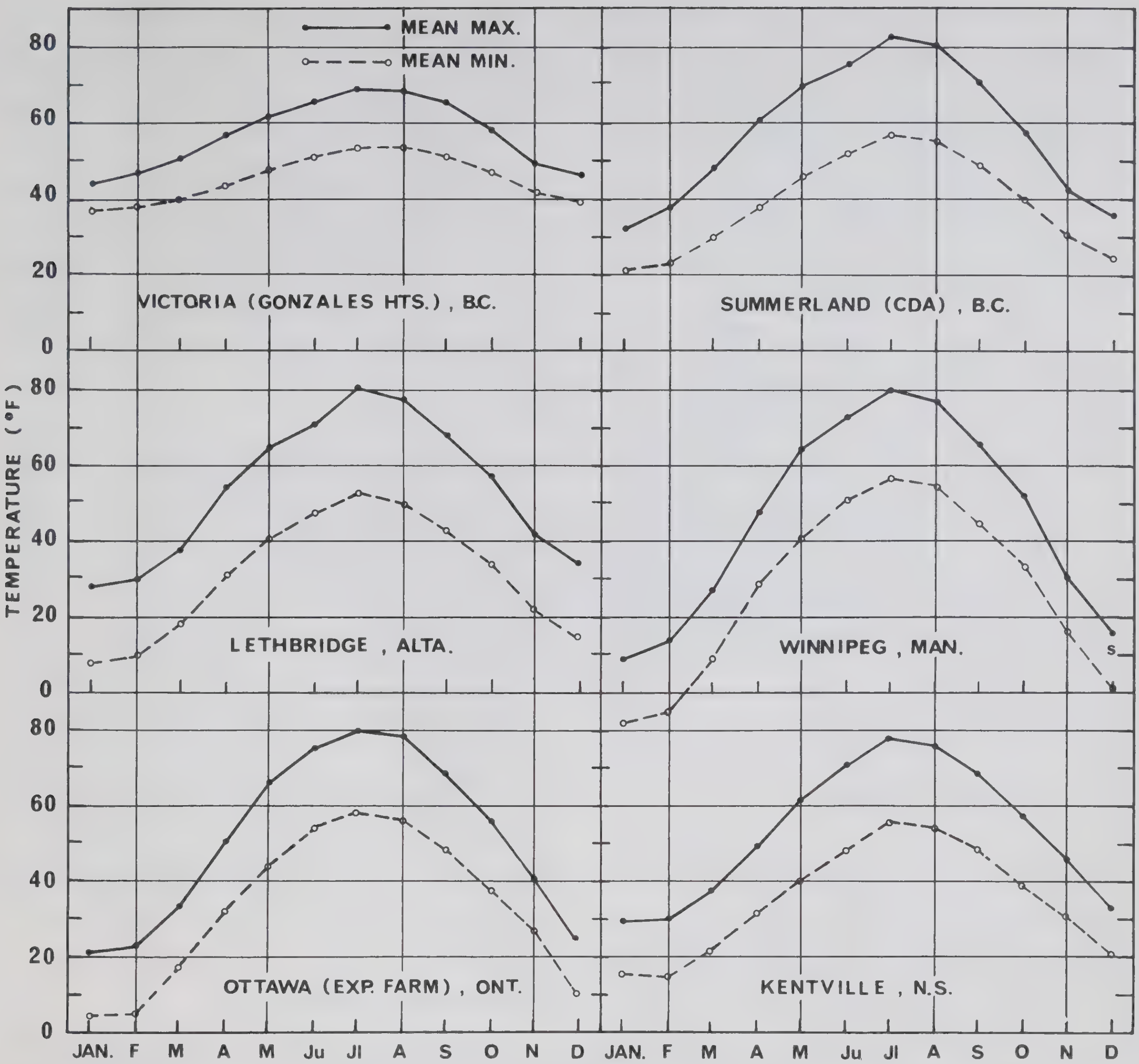


FIGURE 2: Mean monthly maximum and minimum temperatures showing annual variation for six weather stations across Canada.

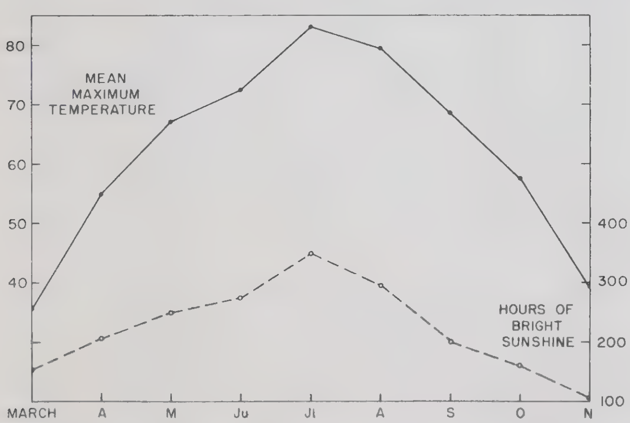


FIGURE 3: Mean monthly maximum temperature and hours of bright sunshine received at Medicine Hat, Alberta.

Saskatchewan must be mentioned. It appears as a depression in June as shown on the graph for Medicine Hat. This characteristic of the temperature regime in the Prairie Provinces correlates with a similar June depression in the sunshine records and a peak in precipitation (Figure 3), thus showing a correlation with increased synoptic activity. Temperature curves for stations in eastern Canada and near the west coast are regularly bell-shaped (Figure 2) and the curves of bright sunshine duration show no depression in June.

July and January Mean Temperatures

For the most part the isothermal maps (Figures 4 and 5) need no explanation. Most of the farm-lands of Canada lie between the 60° and 72° July isotherms.

The 70° July isotherm used to be regarded as a northern boundary for grain corn and soybean production, and the area south of this line in southwestern Ontario still contains the highest concentration of these crops even though new earlier maturing types are extending corn growing northward. The southern Okanagan Valley and Lillòoet-Lytton-Kamloops section of the Fraser and Thompson Valleys are the only other areas in Canada with above 70°F July mean temperatures. July temperatures show much less difference from south to north than January temperatures.

The January isotherms illustrate midwinter conditions. The Pacific coast has by far the mildest winters. Next in order are the southern interior valleys of British Columbia, the Niagara fruit belt and Lake Erie area in Ontario, and the southern tips of New Brunswick and Nova Scotia. The coldest winters felt on Canadian farms occur in the northern fringe areas of Saskatchewan and Manitoba where mean temperatures are under 2°F below zero in January. The 0°F January isotherm runs just north of Lloydminster, Saskatoon, Yorkton, Dauphin, Winnipeg, and Fort William and just south of Kapuskasing and Amos in the Northern Clay Belt of Ontario and Quebec. It is well to remember that the average minimum temperatures are eight to ten degrees colder than the means, for example —10.2°F at Yorkton and —8.6°F at Winnipeg. Southern Alberta, with January temperatures of 15°F is the warmest part of the Prairie Provinces in winter.

Winter Extremes (Mean annual minimum temperatures)

Winter killing of forage crops, fruit trees and a host of horticultural plants is a constant problem in cold countries such as Canada. It is more than a matter of low temperatures, nevertheless any consideration of the problem inevitably includes winter extremes of temperature. Figure 6 is a map based on the averages of the lowest temperatures recorded each winter in the 1931-1960 period. It was prepared for inclusion in this report by the Meteorological Branch, Canada Department of Transport.

As rated by this criterion the favoured status of the west coast is obvious. The similarity of the Okanagan Valley and the Niagara fruit belt is interesting. The Digby end of the Annapolis Valley is also similar but the eastern, Kentville end, has more severe winters. With a figure of —11°F the latter area is similar to the main apple growing areas of Ontario close to Lake Ontario and Georgian Bay. A broad zone extending across the Prairie Provinces lies beyond the —40°F isotherm and this continues eastward across northern Ontario and Quebec. The remainder of Manitoba and Saskatchewan lies between the —40° and —35° isotherms and these temperatures, while not quite so cold, still point up the severity of winters. Southern Alberta is not so extreme, but even there the average of the winter lows is —28°F at Cardston, the warmest station. Nothing more than a highly generalized map can be prepared for British Columbia.

The usefulness of a winter extreme-temperature map depends mainly on the information available as to the survival of plants. When lethal temperatures are known, the best procedure is to give the frequency of occurrence of selected low temperatures, as was done for peaches in Ontario (9). However, the map of mean annual minimum temperatures provides a good rating of the severity of winters.

Growing Season

The growth of grass is slow when daily minimum temperatures fall below 32°F, at that time maximum temperatures would usually be about 20 degrees higher and the mean temperature about 42°F. Thus the dates in spring and fall corresponding to a mean temperature of 42°F are often used as the start and end of the growing season and mapped as in Figures 7 and 8. These dates are earlier in spring and later in fall than the average dates of the last spring and first fall frosts. In drier areas the start is only a few days before the average date of first seeding on well-drained land but in wetter areas this difference amounts to as much as two weeks. The end of the growing season in eastern Canada is about two weeks before the average date that cattle are taken off pasture, so a mean temperature of 38°F would better correspond to this date. With these modifications, these dates provide a rough estimate of the winter barn-feeding period as well as the length of the growing period.

Degree-days Above 42°F

Combining the length of the growing period with mean daily temperatures this index is used as a cumulative measure of the growing period. The figures were derived from mean temperature curves. This involves some error near the start and end of the period as the means include some daily temperatures below 42°F which should be omitted from this computation. They also disregard some daily temperatures above 42°F before the starting and after the ending dates. These errors could be eliminated by working from daily figures, but the advantage so gained would hardly warrant the extra work.

One of the most serious weaknesses of this simple system is that no account is taken of daylength. The rapid growth of plants in the north during the long days is often stressed (3, 4, 16). However, what weight should be given to daylength is not yet established even for grasses. In Canada this problem is minimized by the fact that in the most northerly

FIGURE 4

JULY MEAN TEMPERATURE (°F)

The mean daily temperature for July is the average of the mean July daily maximum and daily minimum temperatures. July is the warmest month of the year except on the Pacific and Atlantic coasts, where August has temperatures similar to July. During the summer the differences in temperature from one area to another are not as great as in winter. July mean temperature in the agricultural areas of Canada vary from just under 60°F in northern British Columbia and the Peace River district to 74°F on Pelee Island, Ontario.

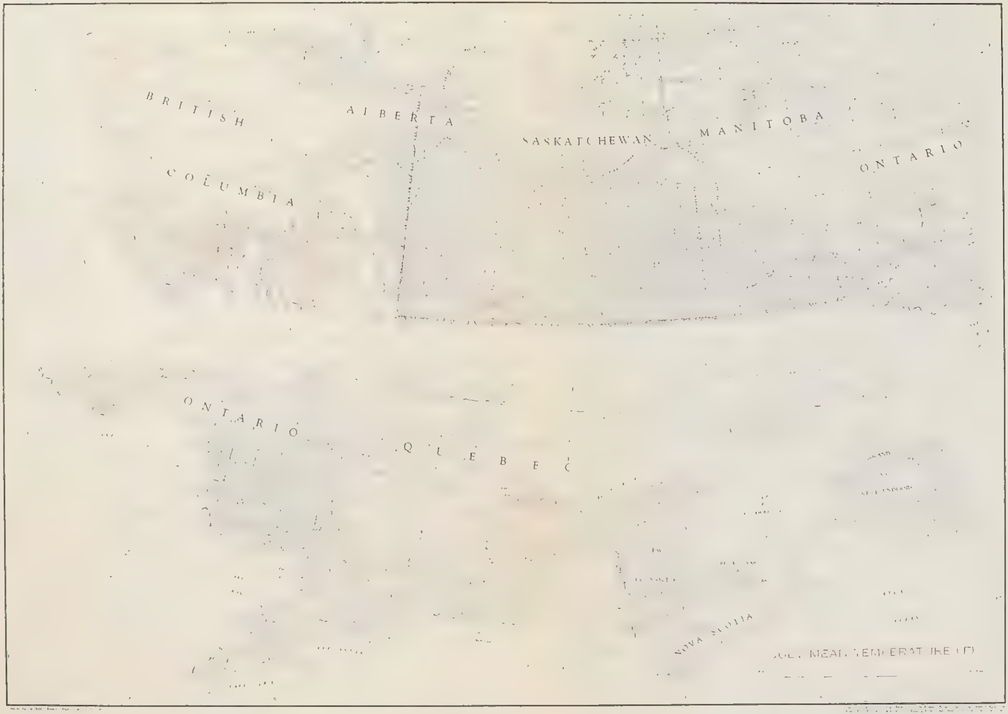
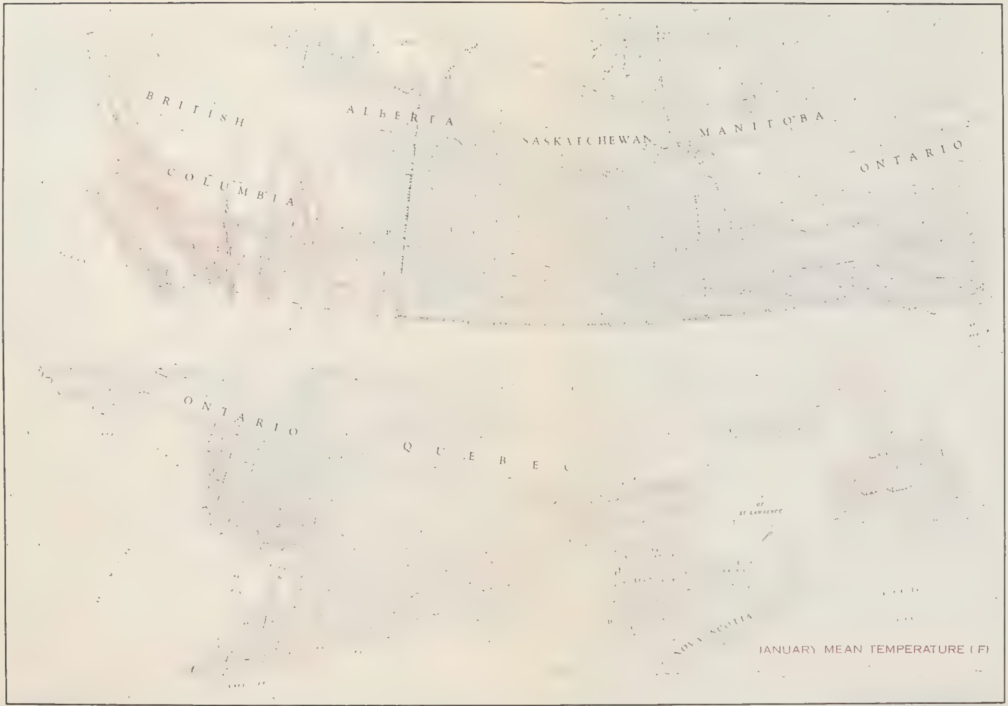

BRITISH COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
ONTARIO
QUEBEC
NOVA SCOTIA
MEAN TEMPERATURE (F)

FIGURE 5

JANUARY MEAN TEMPERATURE (°F)

The mean January temperature is the average of the mean daily maximum and daily minimum temperatures. On the average, January is the coldest month of the year in all of Canada except for parts of southern Ontario and the Atlantic Provinces where average temperatures are usually lower in February. The warmest areas on the west coast have January mean temperatures above freezing. In eastern Canada the Leamington area and the Niagara fruit belt in Ontario and the southern tips of Nova Scotia and New Brunswick have the most moderate winter temperatures. The farming areas with the coldest winter temperatures occur in Manitoba and Saskatchewan.



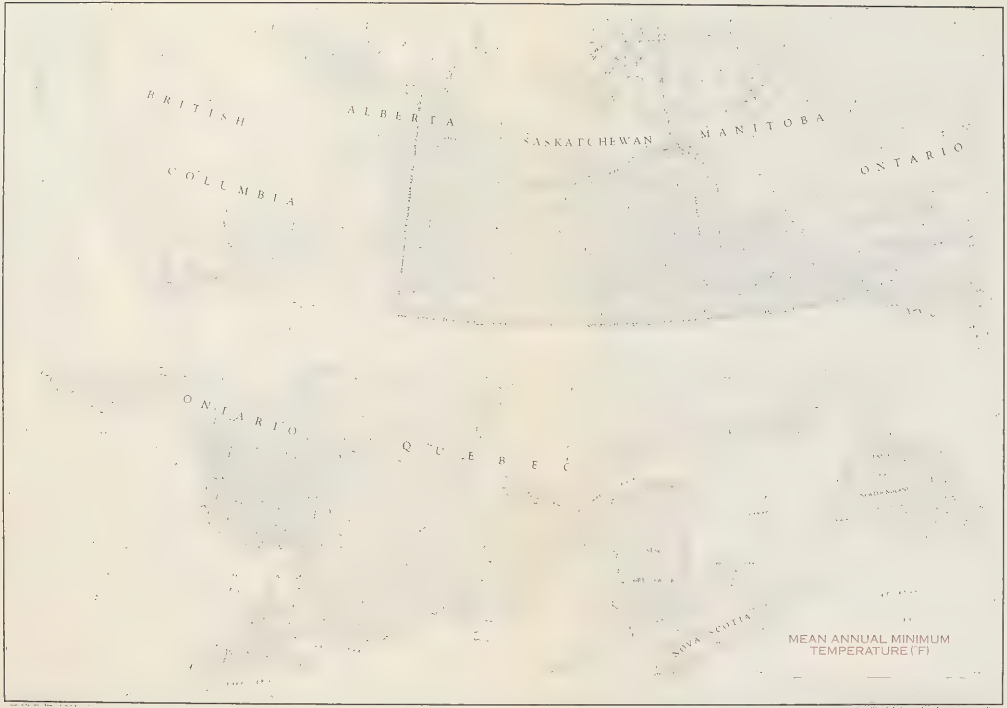
JANUARY MEAN TEMPERATURE (F)

FIGURE 6

MEAN ANNUAL MINIMUM TEMPERATURE (°F)

The lowest temperatures recorded each winter in the 1931-60 period were averaged to determine the mean annual minimum temperatures for this map. It was prepared by the Meteorological Branch of the Canada Department of Transport.

A large area of the Prairie Provinces and northern Ontario and Quebec have the mean annual minimum temperature averaging under 40° below zero.



MEAN ANNUAL MINIMUM TEMPERATURE (°F)

FIGURE 7

START OF THE GROWING SEASON (ABOVE 42°F MEAN TEMPERATURE)

The date of occurrence of a mean temperature of 42°F in the spring was determined from curves drawn through monthly mean temperatures, similar to those shown in Figure 3. This date relates particularly to the start of grass growth in the spring. In the drier areas it corresponds to the start of small grain seeding on well drained soils, but occurs before the average seeding date in humid regions. These dates vary from April 5th near Windsor, Ontario, to May 2nd in the Fort Vermilion, Alberta area.

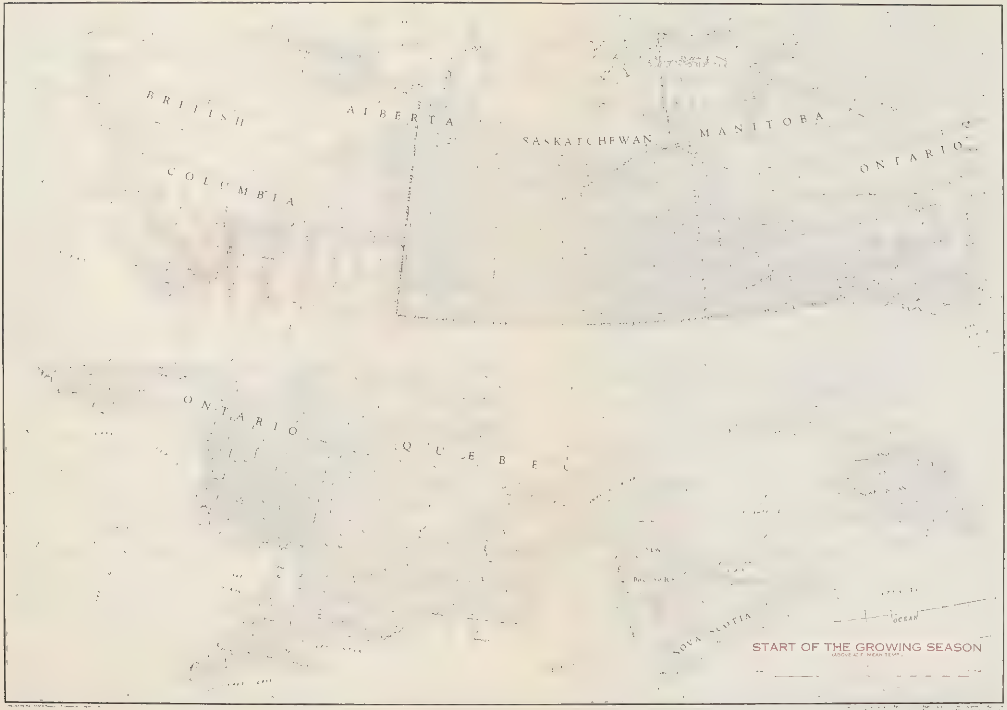
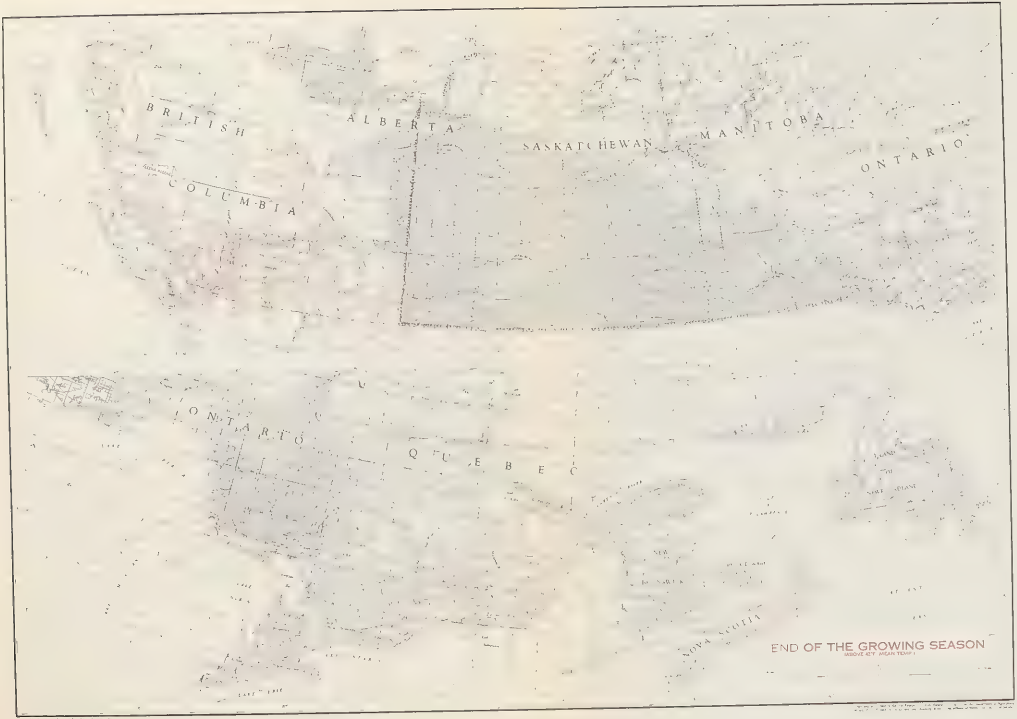

BRITISH COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
ONTARIO
QUEBEC
NOVA SCOTIA
OCEAN
START OF THE GROWING SEASON

FIGURE 8

END OF THE GROWING SEASON (ABOVE 42°F MEAN TEMPERATURE)

The date of occurrence of a mean temperature of 42°F in the fall was determined from curves drawn through monthly mean temperatures, similar to those shown in Figure 3. This date relates particularly to the termination of grass growth in the fall, although it occurs about two weeks before the average date that cattle are taken off pasture in eastern Canada. These dates vary from September 28th in the Fort Vermilion, Alberta area to later than November 10th south of Chatham, Ontario.


BRITISH COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
ONTARIO
QUEBEC
NOVA SCOTIA
END OF THE GROWING SEASON
(ABOVE 42°F MEAN TEMP.)

farming areas of Alberta and Saskatchewan moisture is the limiting factor in the growth of hay and pasture. In spite of its limitations degree-days above 42°F is used as a key index of heat in this account of climate. Values for southern Canada are mapped in Figure 9.

Pelee Island has an average of 4,450 degree-days above 42°F, the highest figure for any spot in Canada. All of Essex County and Kent southwest of Chatham and Wallaceburg average over 4,000 degree-days. Only the Oliver and Osoyoos areas in the southern Okanagan and the Lillooet-Lytton section of the Fraser Valley reach this level in western Canada. The 4,000 line serves nicely as the northern boundary of the area specialized to grain corn, soybeans, sugar beets and other cash crops in southwestern Ontario. In the southern Okanagan Valley the 4,000 degree-days line does not appear to have any special significance for fruit growing. The critical factor for tender fruits in the southern Okanagan Valley and Niagara fruit belt is moderate winter temperatures. Incidentally, the Niagara fruit belt gets just under 4,000 degree-days above 42°F.

It has been found expedient to use intervals of 500 in dealing with the degree-day map starting at the 4,000 line. The 3,500 line in Ontario runs along the north shore of Lake Ontario and passes through London. Grain corn and soybeans are common in this area and it includes most of the flue-cured tobacco belt. In the Okanagan Valley this 3,500 line reaches north of Summerland where the figure is 3,750 and in the Fraser and Thompson Valleys it extends from Vancouver to Kamloops.

In Ontario and Quebec the 3,000 to 3,500 degree-days area lies south of the Shield and extends from Lake Huron to the St. Lawrence Lowland with the Dundalk Upland excluded. It takes in the St. Lawrence Valley as far east as Quebec City. Only the earliest corn hybrids can be matured in this area, especially towards the northern border, but silage corn is an important crop.

In Manitoba, the Red River Valley around Morden has just over 3,000 degree-days, where some silage corn is grown in the rotation and a few farms grow grain corn. In Alberta one station, Medicine Hat, has over 3,000 degree-days so that vicinity must be considered similar to the Red River Valley in this regard. The consensus of opinion is that the Medicine Hat record (3,200 degree-days) is representative of the river valley only and not the adjacent plains. However, the Medicine Hat-Taber vicinity and the Frenchman's Creek area and southward along the Montana border have a similar growing season to the Red River Valley.

In British Columbia, the Okanagan Valley up to Salmon Arm has over 3,000 degree-days, on the average. In the Fraser and Thompson Valleys the 3,000 line runs close to the 3,500 line. It surrounds an area along the coast but slightly inland, north of Vancouver, and takes in most of the inner coastal plain of Vancouver Island as far north as Beaver Creek. These coastal plains have longer, cooler growing seasons than the other sections with the same number of degree-days above 42°F.

The next area, with 2,500-3,000 degree-days, includes a broad belt in the southern part of the Prairie Provinces. It takes in most of the Brown Soil Zone in Alberta, includes the Dark Brown Soils in eastern Saskatchewan and roughly coincides with the northern limit of the Black Soils in Manitoba. Nearly all this area has a frost-free period of 100 days or more, the notable exception being the southeastern corner of Saskatchewan and the adjoining corner of Manitoba. In British Columbia the area having over 2,500 degree-days extends a little farther northward in the valleys than the last area and takes in a broader strip of coastal plain. On Vancouver Island the frost-free period in this coastal strip runs from 151 to 270 days at 11 weather stations. In the Maritime Provinces the area above the 2,500 degree-days line contains nearly all the farm-lands. In Quebec it includes a broad belt of north-draining till plains in the Eastern Townships. It extends up the Ottawa Valley taking in all the settled areas and just reaches the New Liskeard Clay Belt on Lake Temiscaming. It takes in the Sudbury-Sault Ste. Marie settlements, and west of the Lakehead includes the Rainy River region in Ontario.

Compared to the 3,000 to 3,500 area, the 2,500 to 3,000 area in Quebec, Ontario and Manitoba is at a definite climatic disadvantage. However, it is distinctly better than the colder areas beyond the 2,500 line. This latter advantage fails to hold true in Saskatchewan and Alberta where wheat is dominant. For that crop, 90 frost-free days is the critical limit and it occurs farther north than the 2,500 degree-day line. In fact the higher temperatures south of the 2,500 degree-day line appear to be a disadvantage. Even though the Weyburn-Estevan area receives more rainfall, Hutcheon *et al.* (6) give it the same climatic rating as the Saskatoon-Macklin area. Possibly the higher temperatures accentuate the effects of droughts in the former area.

Most of the Peace River region is rated at just over 2,000 degree-days above 42°F. The frost-free period varies widely, from 59 to 105 days at the twelve weather stations within the area. The only areas where agriculture is being carried on north (coldward) of the 2,000 degree-day line is in northwestern Saskatchewan

and Alberta and in the northern valleys and plateaux in British Columbia and along the Gaspé coast.

The Frost-free Period

The probability of frost injury to crops after certain dates in the spring and before certain dates in the fall is obviously of vital concern to the farmer. Usually, when describing climate the average dates of the last spring and first fall frosts and the average number of frost-free days are given. The usual procedure is to base "frost" on the occurrence of 32°F or lower in the Stevenson screen (2). It is well known that for hardy crops a lower temperature would be more applicable; with cereal grains, for example, a later date for the first killing fall frost based on 28°F would be preferable. On the other hand the average date gives only a 50 per cent chance of avoiding frost damage; for better odds one would point to an earlier date. These two factors tend to balance, so the average date based on 32°F is used. A more serious problem is the great variability in frost dates at adjacent stations, mainly because of local topography, soil differences and the effect of adjacent bodies of water.

To facilitate the drawing of generalized frost maps some means of overcoming the variations in the published frost dates (2) based on occurrences of 32°F or lower is necessary. To this end a special study has been made. As a starting point 47 weather stations with over 45 years of frost records were selected. The frost dates from these stations were then plotted on normal temperature curves based on the same period at these same stations. Several procedures were used including the one used in 1938 in Ontario by Putnam and Chapman (11) in which frost dates were taken as the date of occurrence of 32°F plus the mean daily range on the mean temperature curve. However, that method was found to be no better and more difficult than the use of certain points on the mean minimum temperature curve. These points, listed in the table below, were then used to derive last spring and first fall frost dates for about 700 stations with records from 1931 to 1960.

Mean Minimum Temperatures Corresponding to the Average Dates of Last Spring and First Fall Frosts

	°F
British Columbia	40.0
Prairie Provinces, according to elevations in feet:	
Over 4,000	40.0
3,500 - 4,000	40.5
3,000 - 3,500	41.0
2,600 - 3,000	41.5
2,300 - 2,600	42.0
2,000 - 2,300	42.5
Under 2,000	43.0
Eastern Canada	43.5

Using this empirical scheme three frost maps have been drawn (Figures 10, 11, 12) showing the average date of the last spring and first fall frosts and the average length of the frost-free period.

The south tip of Vancouver Island, as represented by Victoria, seldom gets frost after April 1, and the average occurrence of last spring frosts falls in the middle of March. This area has much the longest frost-free period of any part of Canada. The other extreme is also well represented in British Columbia on the mountain crests where frosts occur periodically in mid-summer, and spring and fall frosts can only be separated arbitrarily by using July 15 as a dividing line. In the Okanagan Valley, where frosts are a critical factor in fruit and vegetable production, there is much less variability in frost dates from year to year than on the coast. However, here, as in all the valleys of the interior the incidence of frosts varies widely over the terrain. The average date of the last spring frost is around May 1 in the Okanagan below Vernon and in the Thompson and lower Fraser Valleys below Kamloops.

In the Prairie Provinces, the frost-free period starts earliest in southern Alberta, before May 20 in the Lethbridge-Medicine Hat-Manyberries area. The dates in southern Manitoba are a little later. At the other extreme, in the northern fringe areas the average date of last spring frost is June 15 or later.

In the Northern Clay Belt of Ontario and Quebec the average date of the last spring frost is about June 10, a week earlier than in the central part of the Peace River district. The comparable date is June 1 at New Liskeard, May 21 at North Bay, May 17 at Orillia, May 14 at Guelph, May 14 at Delhi, and May 1 at Leamington and Harrow. In the Atlantic Provinces the last spring frosts occur before May 24 in most of the settled lowland areas on the average, except in Newfoundland where a comparable date of June 10 applies to a few favoured areas.

With field crops, the occurrence of the first killing frosts in the fall is a more serious event than the last in the spring. The great contrast mentioned in regard to spring frosts in British Columbia also exists with regard to fall frosts. On the mountain tops, frosts may occur anytime in summer. At Victoria, fall frosts very rarely occur before November 1; on November 9 there would be a 90 per cent chance of escaping frosts and on December 7 a 50 per cent chance of avoiding frost damage. In the Prairie Provinces the northern fringe of the agricultural areas have a serious frost hazard north of the August 25 isopleth. Areas with average first fall frost dates after September 1 are regarded as having moderate frost hazard for cereal grains,

FIGURE 9

DEGREE-DAYS ABOVE 42°F

Degree-days, above 42°F, sometimes called growing degree-days expresses the length and warmth of the growing season in a single figure. These values are based on normal monthly temperatures. The number of degrees above 42 were accumulated for all days between the dates of occurrence of 42° in the spring and in the fall for around 640 weather stations in southern Canada. These totals vary from over 4250 degree-days south of Windsor, Ontario, to less than 1750 in the Prince George area of British Columbia.

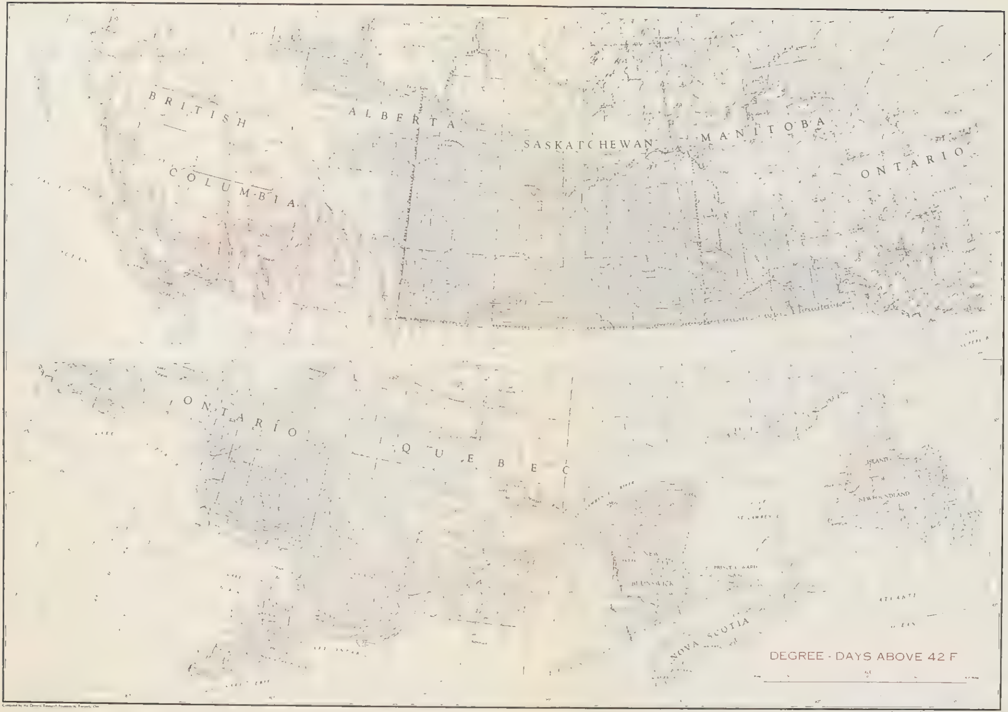

BRITISH
COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
ONTARIO
QUEBEC
NEWFOUNDLAND
NOVA SCOTIA
DEGREE - DAYS ABOVE 42 F

FIGURE 10

MEAN SPRING FROST DATE

The mean spring frost date as published (2) is the average of the dates of last occurrence of an official "screen" temperature of 32°F or less in the spring for the period of record of any weather station. In order to avoid some of the variability in these dates and to make use of short-term records for this map an empirical scheme was used. This scheme utilizes the mean minimum temperature curves based on 1931-1960 climatic data. The mean minimum temperatures corresponding to the average date of last spring frost used in this scheme were: 40°F in British Columbia; 40 to 43°F according to elevation in the Prairies and 43.5°F in eastern Canada. The resulting dates vary in the agricultural regions of southern Canada from April 1st on southern Vancouver Island to June 15th in the Peace River region.

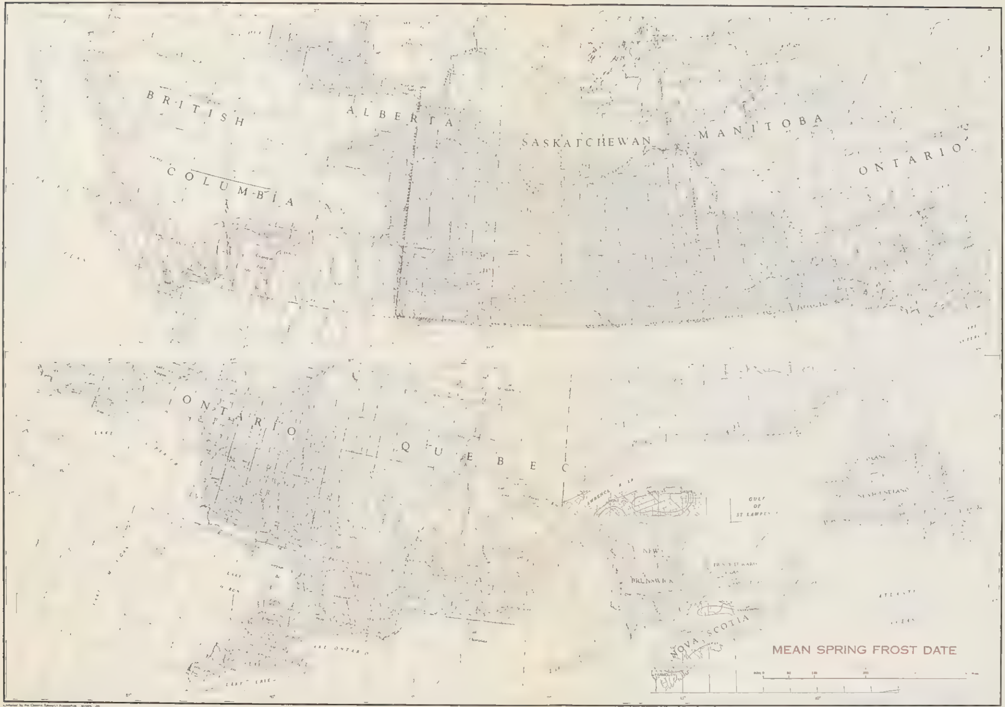

BRITISH COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
ONTARIO
QUEBEC
NEW BRUNSWICK
NOVA SCOTIA
GULF OF ST LAWRENCE
MEAN SPRING FROST DATE

FIGURE 11

MEAN FALL FROST DATE

The mean fall frost date as published (2) is the average of the dates of first occurrence of an official "screen" temperature of 32°F or less in the fall for the period of record of any weather station. In order to avoid some of the variability in these dates and to make use of short-term records for this map an empirical scheme was used. This scheme utilizes the mean minimum temperature curve based on 1931-1960 climatic data. The mean minimum temperatures corresponding to the average date of first fall frost used in this scheme were: 40°F in British Columbia; 40 to 43°F according to elevation in the Prairies and 43.5°F in eastern Canada. The resulting dates vary in the agricultural regions of southern Canada from August 20th in the Peace River region to December 1st on southern Vancouver Island.

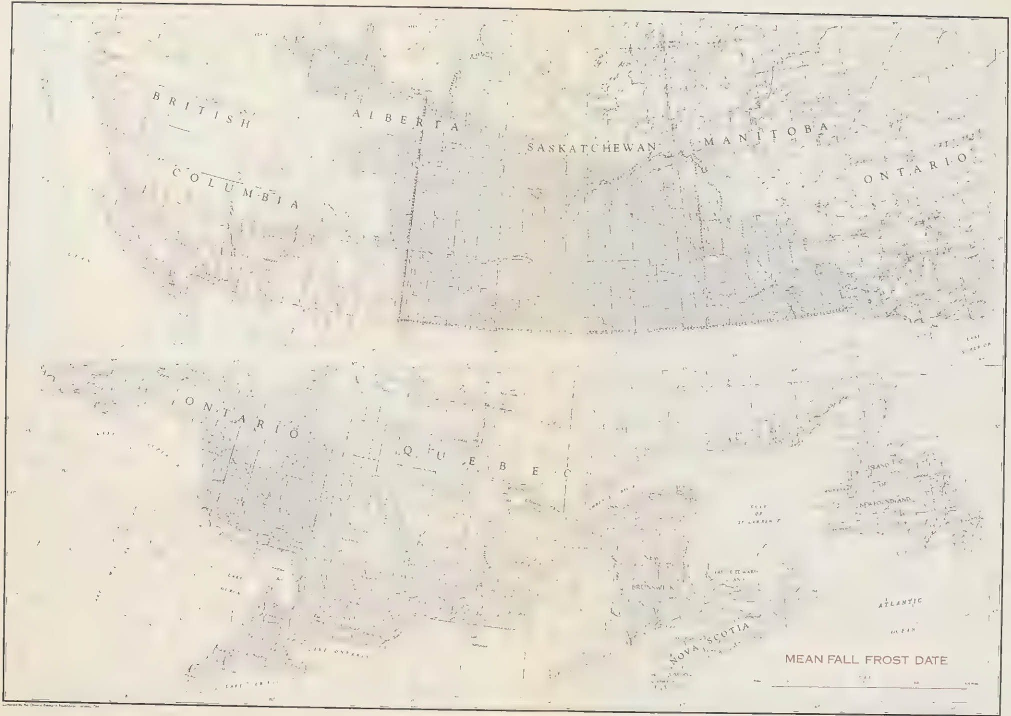
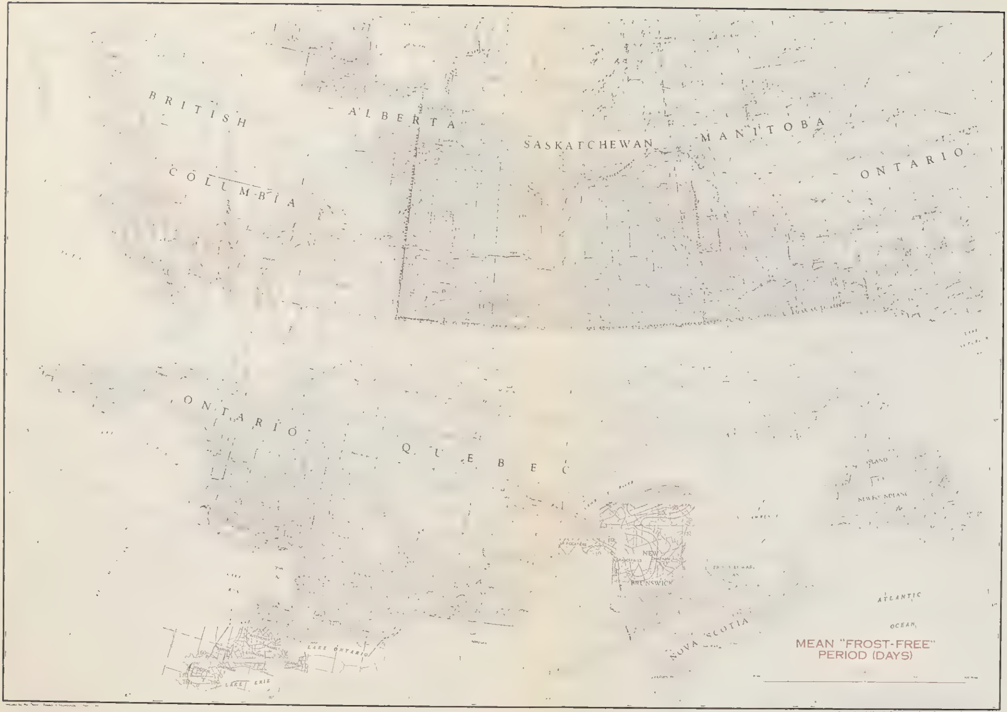

BRITISH
COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
ONTARIO
QUEBEC
NEWFOUNDLAND
NOVA SCOTIA
ATLANTIC
MEAN FALL FROST DATE

FIGURE 12

MEAN "FROST-FREE" PERIOD (DAYS)

The number of days between the mean spring and fall frost dates is taken as the frost-free period. The number of "frost-free" days vary from around 60 in the Peace River region to 220 on the southern tip of Vancouver Island.


BRITISH
COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
ONTARIO
QUEBEC
NEW
BRUNSWICK
NOVA SCOTIA
LAKE ONTARIO
LAKE ERIE
ATLANTIC
OCEAN
MEAN "FROST-FREE"
PERIOD (DAYS)

while in warmer areas serious losses from frost injury are rare.

In the Northern Clay Belt of Ontario and Quebec the average first fall frost date is about September 4 and this only applies to high ground. On low ground, especially on peat, fall frosts occur earlier. Frost is a hazard to grain crops in any area where the first fall frost comes before September 10, on the average. At this season Newfoundland is more favoured than the Northern Clay Belt in regard to frosts, whereas the reverse is true in the spring. The Temiscaming Clay Belt, the Lake St. John district and the Gaspé shore area have similar fall frost dates. The lowlands of Nova Scotia and New Brunswick and Prince Edward Island are similar in this regard to the main body of southern Ontario and also the St. Lawrence Lowland above Trois-Rivières. The moderating influence of the Great Lakes on temperatures is clearly shown by the fall frost map and the difference inland is accentuated by the upland south of Georgian Bay. The map also shows the favoured position of southern Kent and Essex Counties.

In both spring and fall the difference between the two dates that allow (a) a 50 per cent chance and (b) a 90 per cent chance of avoiding killing frosts is roughly 14 days except on the Pacific coast where the difference is as much as a month in extreme cases.

Figure 12 shows the average length of the frost-free period. The highest recordings of 240 days are on the southern coastal belt of Vancouver Island. Gonzales Heights in Victoria is the only station that has indicated a longer frost-free period. If plotted, a 200-day isopleth would extend up the Fraser Valley to Agassiz. Next in order, after the coastal plains, come the southern Okanagan Valley in British Columbia, and the Niagara fruit belt and south Kent and Essex Counties in Ontario, both with 160 to 175 days. In Nova Scotia only favoured spots on the south coast have 160 days, the Annapolis Valley being rated at about 140 days. In Newfoundland only some coastal slopes have over 120 days, and on the coast of the Gaspé peninsula a figure of 115 days is more applicable. In the St. Lawrence-Ottawa Lowland and southern Ontario the edge of the Shield corresponds roughly with the 125-day line. The warmest parts of the Prairie Provinces have barely 125 frost-free days on the average. However, for the available varieties of wheat, frost is not a serious hazard in those areas with over 90 days, except in Manitoba where under wetter conditions 100 days would be a better limit. By serious hazard, it is meant that the wheat is only reduced in quality by one or two grades and with practically no loss in yield. Severe freezing which reduces quality to feed grade and cuts down yield is rare.

The 90-day line does not agree with agronomic experience in all sections. In Saskatchewan, the lower Saskatchewan Valley area as represented by weather stations at Prince Albert, Nipawin, and Cumberland House have about 95 frost-free days on the average, but the frost hazard is appreciable in this area. In Alberta, the Lacombe area is not regarded as having a serious frost hazard, but according to the weather records it has less than 90 frost-free days.

North of the 80-day line the frost hazard becomes severe. However, this line cannot be drawn with much confidence due to wide local variations because of topography. These topoclimatic variations have not been measured except in a few places in the Peace River district (1). This matter needs urgent study in order to rate established farm-land and to guide new settlement.

Corn Heat Units

Since 1964 the maturity ratings of corn hybrids, recommended for production in Ontario, has been expressed in terms of "corn heat units" (C.H.U.). The growing season from planting time to a fall frost date has been expressed in the same terms on a map of the province. The date coinciding with a mean temperature of 55°F in the spring was used as the planting date. The fall frost date selected was that before which there is a 10 per cent chance of 32°F or lower in the Stevenson screen.

The "corn heat unit" formula makes use of both maximum and minimum daily temperatures. The relationship to maximum temperatures is parabolic, rising from zero at 50°F to a peak of 33 at 86°F, then diminishing. Degrees above 40°F are computed from daily minimum temperatures. The two are then averaged to give a single figure for each day of the growing season. The formula is expressed as follows:

$$\text{C.H.U.} = \sum_{i=1}^{n} \frac{(T_{min} - 40) + (4.39T_{max} - .0256T^2_{max} - 155.18)}{2}$$

where T_{min} and T_{max} are the average minimum and maximum temperatures for each day (i) taken from curves like those shown in Figure 4.

This system has been applied only in the warmer areas of Canada, where corn production is possible, as seen in Figure 13. In Ontario, corn is grown for grain in areas defined at 2,500 C.H.U. and more. In addition, some corn is grown for silage in areas with as few as 2,100 C.H.U. Other areas in Canada with 2,100 or more include south-central Manitoba, the South Saskatchewan River Valley area between Medicine Hat and Taber, Alberta, most of the agricultural areas in southern British Columbia including all of the Okanagan Valley, lower Fraser and Thompson River

Valleys and the southeastern coastal plains of Vancouver Island, the middle St. Lawrence region of southern Quebec, the lower St. John and Annapolis Valleys and Prince Edward Island. Some corn is grown for silage in most of these areas, although not to the same extent as in southern Ontario. Some grain corn is produced in the lower Fraser Valley, southern Manitoba and Quebec. Of these three areas, the risk is greatest in southern Manitoba, as the Morden-Morris-Emerson area just exceeds 2,300 C.H.U. This area is comparable to the edges of the Dundalk Upland and Renfrew County in southern Ontario.

Grain corn, oats and barley are used mainly for energy in livestock feed. In areas where the growing season is ample, corn is a more efficient producer of energy than barley. However, the advantage that corn has over barley decreases as the growing season shortens and cuts off with our present hybrids at about the 2,300 C.H.U. line. The development of new earlier hybrids would push the northern fringe of corn production towards the 1,900 C.H.U. line.

The 1,900 C.H.U. line corresponds roughly to the 2,500 degree-day line, except in the Brown Soil Zone in southern Alberta and Saskatchewan where it shifts close to the 2,750 degree-day line. This shift is due to minimum temperatures being up to three degrees lower than at stations along the 2,500 degree-day line in more humid regions. Minimum temperatures are given more weight in the "corn heat units" system than in degree-days above 42°F.

It is possible that for the dry areas an earlier planting date should be taken. A mean temperature of 55°F occurs in late May or early June in southern Alberta and Saskatchewan. As the soils are generally drier and likely warmer at this air temperature than in Ontario, an earlier planting date may be warranted. If so, 100 units may be added to the C.H.U. rating indicated on the map for each week prior to the 55° date.

MOISTURE

Five maps have been prepared in dealing with moisture, all of which are based on average data for the 1921-1950 period. The first two, mean annual and mean May-to-September precipitation, are based directly on the records. The others involve empirical estimates of water needs and are assessments of average yearly deficiency of precipitation and actual evapotranspiration computed by the Thornthwaite method (15).

Average Annual Precipitation

Average annual precipitation has obvious weaknesses as a moisture index for agriculture and forestry. It will suffice to point out that the coastal plains of southern British Columbia receive high annual precipitation due to wet winters, but the summers are dry so the annual figures are quite misleading. However, in the Prairie Provinces where there is a low winter and higher summer precipitation regime (Figure 14) the mean annual figures are useful and have become well known. For this reason, if for no other, the inclusion of a mean annual precipitation map is warranted (Figure 15).

The highest annual precipitation in Canada south of latitude 59° is 175 inches — recorded at Ocean Falls. Some other sections of the Pacific slope of the Coast Range reputedly receive up to 25 inches more than this. The other extreme, 7.4 inches, is also recorded in British Columbia at Ashcroft in the Thompson Valley below Kamloops. Here and in the southern Okanagan Valley is found the driest climate in Canada.

In the Prairie Provinces mean annual precipitation is under 12 inches north, west, and south of the Cypress Hills. From this low point it increases fairly uniformly to 17 or 18 inches in the Edmonton area, to 15 or 16 inches in the Prince Albert-Melfort area and to 20 inches in the Winnipeg area. East of Winnipeg it increases rapidly to over 26 inches at Fort Frances, Ontario, and there is a steady increase across northern Ontario to over 40 inches in the Saguenay district of Quebec. The southeast coasts of Newfoundland and Nova Scotia receive about 55 inches, on the average. On the slopes east of Lake Superior, Georgian Bay and Lake Huron up to 38 inches is recorded. These three areas in the lee of the Great Lakes are the snowbelts of Ontario, the average snowfall being 80 to 120 inches a year. Average snowfall in eastern Canada reaches a maximum of over 160 in the Saguenay district of Quebec and over 100 inches falls on a broad area of the Laurentian Uplands north of Montreal. The great upsurge in the popularity of skiing in recent years has resulted in snow being a recreational asset. The snowy mountain slopes in accessible areas in British Columbia are particularly favoured for this sport. The heaviest snowfall in Canada and of course the greatest accumulation of snow occurs on the mountains of British Columbia. For instance, the normal snowfall at Glacier is 370 inches and this certainly is not the maximum.

Throughout southern Ontario and Quebec and the Atlantic Provinces precipitation is fairly evenly distributed throughout the year (Figure 14). In the drier areas, moisture deficiencies are common in summer and early fall, but in the broad areas of higher precipitation wetness during the growing season is a more serious problem for farmers than drought.

Average May to September Precipitation

Average May to September precipitation gives a measure of moisture in the main part of the growing

FIGURE 13

CORN HEAT UNITS

Corn heat units (C.H.U.) are based on averages of monthly maximum and minimum temperatures during the corn growing season. Curves based on the 1931-60 normal temperatures were used for this purpose. Heat units for each day are accumulated from the average date of occurrence of a mean temperature of 55°F in the spring to the date before which there is a 10% probability of frost in the fall using the following equation:

$$C.H.U. = \sum_{i=1}^{n} \frac{(T_{min} - 40) + (4.39\, T_{max} - .0256\, T^2_{max} - 155.18)}{2}$$

Values for T_{min} and T_{max} are the average minimum and maximum temperatures for each day (i) in the corn growing season as defined above.

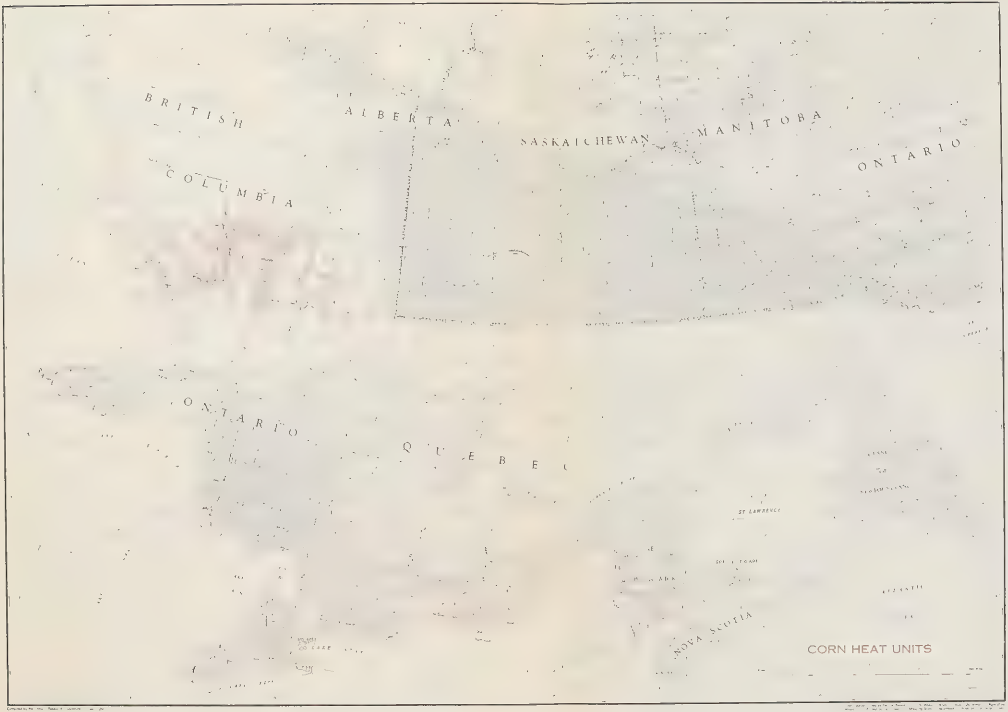

BRITISH
COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
ONTARIO
QUEBEC
ST LAWRENCE
NOVA SCOTIA
CORN HEAT UNITS

FIGURE 14

MEAN MONTHLY PRECIPITATION (INCHES)

Bar charts are used to show the average precipitation in each month of the year for several selected stations in southern Canada. The chart for Victoria illustrates the high winter—low summer precipitation occurring on the west coast and that for Summerland illustrates the year-round dryness in the valleys of southern British Columbia. The high summer—low winter precipitation from the Rockies to northern Ontario and Quebec is apparent, as is the general increase in an easterly direction of total annual precipitation. From southern Ontario eastward precipitation is fairly evenly distributed from month to month throughout the year, except in Newfoundland where the high winter—low summer distribution prevails again. The station with the greatest mean annual amount of precipitation (Ocean Falls, B.C.) could not be shown as means in all months exceed 6 inches and those in October, November and December exceed 23 inches.


BRITISH
COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
ONTARIO
QUEBEC
CHARLOTTETOWN
NEWFOUNDLAND
MEAN MONTHLY
PRECIPITATION (INCHES)

FIGURE 15

AVERAGE ANNUAL PRECIPITATION (INCHES)

The total precipitation in any year is the sum of the total rainfall and the water equivalent of the total snowfall for that year. Usually a specific gravity of 0.1 is assumed for freshly fallen snow. The average annual amount of precipitation varies from under 12″ in the dry valleys of southern British Columbia and in the South Saskatchewan river valley north of Medicine Hat to well over 150″ in the Ocean Falls—Prince Rupert area on the west coast.

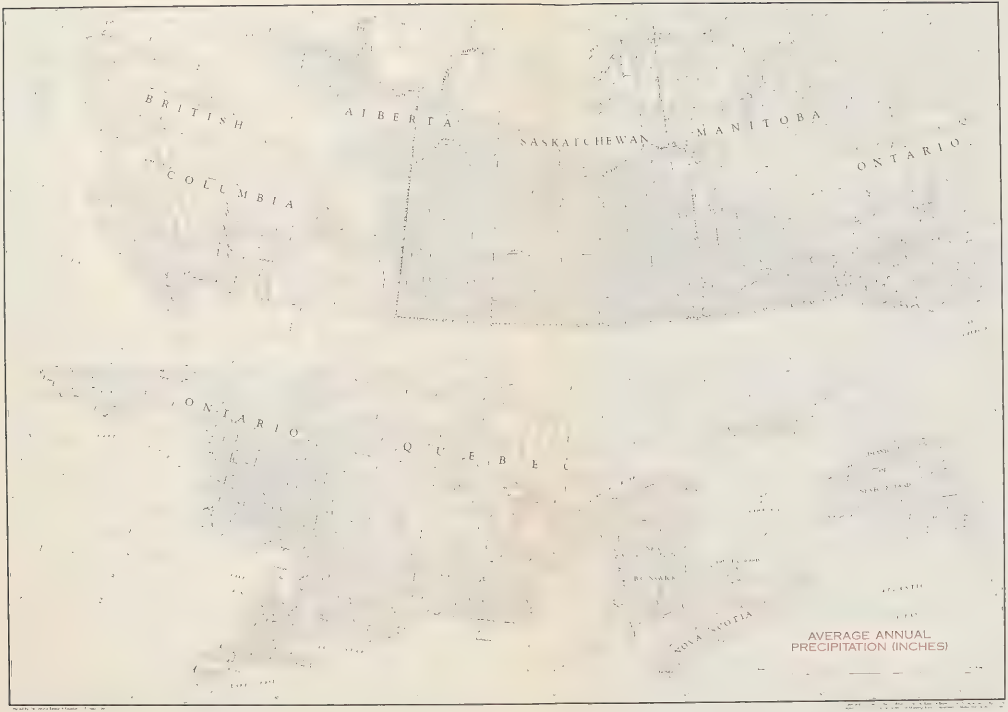

BRITISH COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
ONTARIO
QUEBEC
NOVA SCOTIA
AVERAGE ANNUAL
PRECIPITATION (INCHES)

FIGURE 16

AVERAGE MAY TO SEPTEMBER PRECIPITATION (INCHES)

May to September precipitation was selected as a measure of growing season precipitation. In the Prairie Provinces where moisture is critical for grain crops the period April to August might serve the purpose better. However, this would not change the pattern greatly and in all the other farming areas of Canada the May to September period is preferable. Average May to September precipitation varies from 4″ in the southern Okanagan Valley to 20″ or more in some of the agricultural areas of Quebec and the Atlantic Provinces.

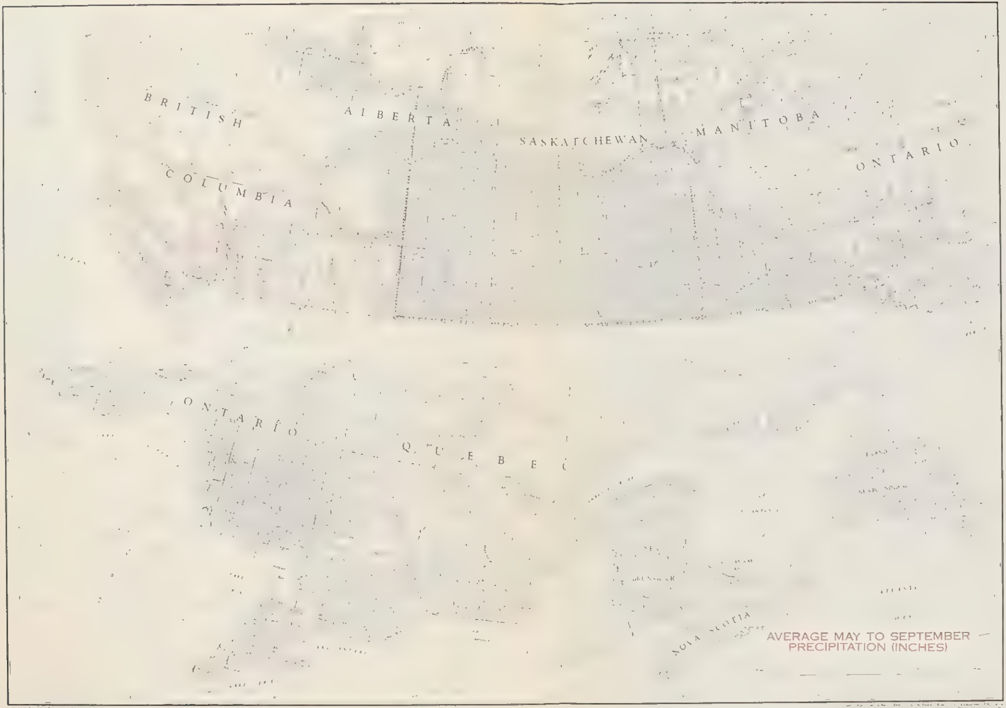
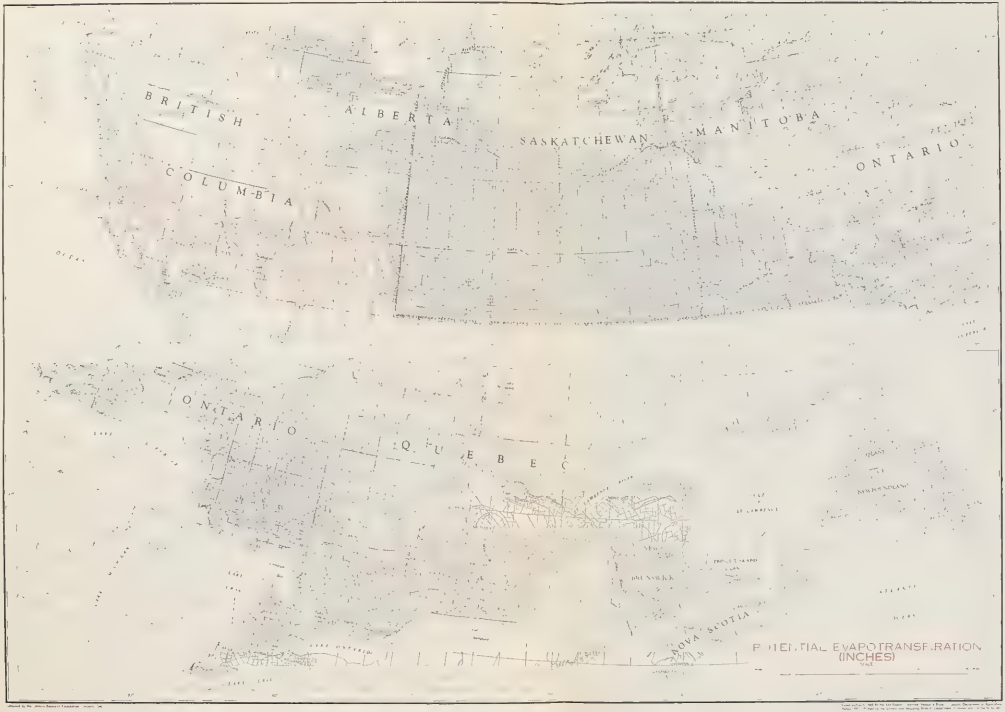

BRITISH COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
ONTARIO
QUEBEC
NOVA SCOTIA
AVERAGE MAY TO SEPTEMBER
PRECIPITATION (INCHES)

FIGURE 17

POTENTIAL EVAPOTRANSPIRATION (INCHES)

The average annual potential evapotranspiration in inches of water was computed according to the Thornthwaite method (15) for all stations with temperature records, as it is based on mean temperature and daylength. Potential evapotranspiration serves as a photothermal or heat index as well as an estimate of water need. Values are determined for months with mean temperatures above 32°F, increasing with temperature and with daylength up to latitude 50°. An adjustment factor increases the relative rating in cooler climates, so that when compared to degree-days above 42°F the percentage decrease in rating from south to north is much less. Potential evapotranspiration drops only 20 per cent from Chatham, Ontario (25″) to the Peace River region (20″) whereas day-degrees above 42°F drop 50 per cent from 4000 to 2000 between the same two regions.


BRITISH COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
ONTARIO
QUEBEC
NEWFOUNDLAND
NOVA SCOTIA
POTENTIAL EVAPOTRANSPIRATION
(INCHES)

season. In contrast to annual precipitation, it shows dry conditions on the coastal plains of British Columbia and reflects the summer maximum of precipitation in central Canada (Figure 16). It gives a similar distribution pattern to annual precipitation in eastern Canada. The map is self-explanatory and perhaps is best used together with the map of average water deficiency for an appraisal of moisture.

In Saskatchewan and Alberta, a puzzling discrepancy appears between this precipitation map and soil zones. The Black Soil Zone between the Melfort and the Lloydminster areas receives less precipitation than the remainder of this Zone. The 10-inch May to September isohyet coincides with the Brown-Dark Brown Soil Zone boundary in the south, but crosses both the Dark Brown and Black Soil Zones towards the north. This is not just a peculiarity of the 1921-1950 weather records; the 1901-1960 records at 25 stations show the same pattern. The water deficiency map more nearly conforms to the soil zone map but the discrepancy is still present.

Potential Evapotranspiration

Potential evapotranspiration is regarded as the amount of water used by evaporation from the soil and transpiration from the plants when there is a dense cover of vegetation and continuously moist soil. Simply, it is an estimate of water need. In this case the computations were made by means of the Thornthwaite method (15). Assuming that all the precipitation enters the soil as long as the soil is below field capacity, and that four inches of water may be held in the soil for use by plants, it is possible to compute yearly amounts of water deficiency and water surplus.

Average annual potential evapotranspiration based on 1921-1950 normal temperatures is shown in Figure 17.

The highest potential evapotranspiration values in Canada, over 27 inches, are those for Lillooet and Lytton in the middle Fraser Valley in British Columbia. Several of the stations in the Okanagan Valley, the Fraser River Delta area and the coastal plains in southern British Columbia have average annual potential evapotranspiration values of about 26 inches, and so has Pelee Island and Harrow in southwestern Ontario. Most of southern Ontario and southern Quebec are rated at 22-24 inches by this index. The southern parts of the Prairie Provinces are rated at about 22 inches, which is similar to much of the lowland areas in the Atlantic Provinces. In the northern fringe areas for agriculture 20 inches is a common figure.

Average Annual Water Deficiency (4″ Storage)

The figures for water deficiency, expressed in inches, were derived by the Thornthwaite method assuming four inches of soil moisture storage as mentioned before. They were based on the 1921-1950 normal monthly records and are slightly lower than those derived by Dr. A. H. Laycock for the Prairie Provinces (8). He worked out a value for each season using data for individual months, then obtained an average for the 1921 to 1950 period. The difference in the values derived by these two procedures is about two inches in the moister areas and one inch in the drier areas (Figure 18). The difference between them is fairly consistent and so the much shorter procedure based on normal figures was used for this account of the whole of Canada.

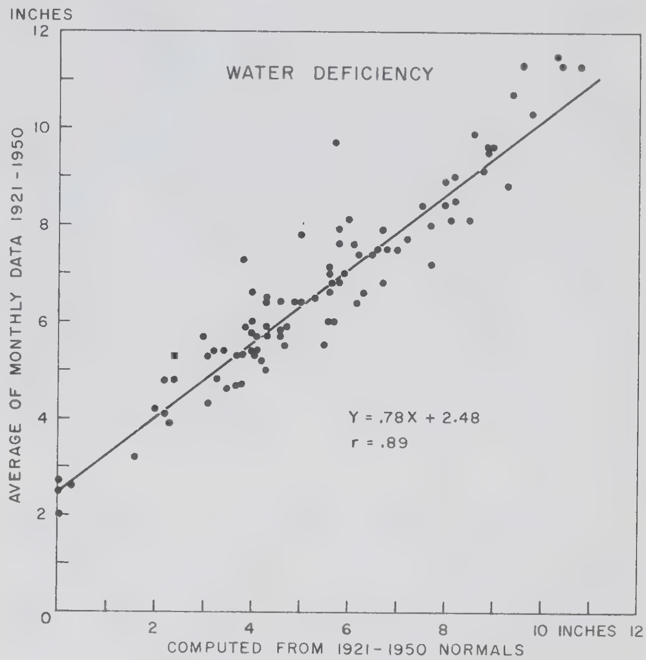


FIGURE 18: Relation between water deficiency computed from monthly weather data for each year and from 1921-1950 normals.

The water-deficiency map (Figure 19) emphasizes the dryness of the middle Fraser and Thompson Valleys and southern Okanagan Valley in British Columbia with values of over 16 inches. The driest parts of Alberta and Saskatchewan are rated at 10 to 12 inches. In Alberta the water-deficiency map conforms quite well to soil zones. However, in Saskatchewan the Dark Brown and Black Soil Zones west of the Quill Lakes and Melfort have a drier rating than the area southeast of these lakes. This is the same peculiar discrepancy mentioned in the discussion of May to September precipitation.

In southern Manitoba the average deficiency is four to six inches which is similar to Essex and southern Kent Counties and the Niagara fruit belt in Ontario. The deficiency figures reach zero between Lake-of-the-Woods and the Lakehead and continue at that level across northern Ontario and most of Quebec to the

east coast. Under the cool conditions of this region the benefit gained from lack of droughts is offset by excess water particularly at seeding and harvest time when it is a real detriment to farm operations and crop growth.

In southern Ontario and Quebec, water-deficiency figures reach zero north of London and in the Eastern Townships respectively. Wetness is not as serious a problem here as in cooler regions, but it does appear to almost nullify any advantage that areas with zero have over those with up to four inches of average water deficiency.

Actual Evapotranspiration (4″ Storage)

In the Thornthwaite climatic classification (15) the water loss from moist soil covered with vegetation is called potential evapotranspiration. In regions where moisture is inadequate evapotranspiration will be less than the potential amount. A soil moisture holding capacity of four inches was assumed. From the beginning in spring "actual" evapotranspiration is accumulated at the potential rate until the soil moisture is all withdrawn, then it is governed by precipitation until this exceeds the potential rate when actual again becomes the same as potential. These computations were based on 1921-1950 normal precipitation and temperature records. The distribution is mapped in Figure 20.

Because it is based on the amount of water used throughout the growing season the average figures for actual evapotranspiration should indicate the climatic potentiality for hay and pasture. The average yields of hay at 21 experiment stations across Canada (12) when plotted against average "actual evapotranspiration" for the same station show a good correlation (Figure 21).

The actual evapotranspiration map shows some interesting contrasts and similarities in widely separated parts of Canada. The highest growth potential for the whole season is indicated by a figure of 25.3 inches at Stave Falls in the lower Fraser Valley and this is supported by high figures for several coastal stations on the mainland as far north as Ocean Falls and on Vancouver Island. The value at Clayoquot on the west coast of Vancouver Island is 25.1 inches. This coastal strip consists mainly of forest with a few scattered farming settlements. The forest, dominated by large western red cedars, western hemlocks and Douglas-firs, is the finest and most productive in Canada. Most of the lower Fraser Valley between New Westminster and Agassiz, in spite of dry midsummers, is represented by actual evapotranspiration values of over 23 inches.

On the Atlantic Coast the highest climatic potential for hay and pasture is indicated by a value of 23.8 inches at Yarmouth in the south-western tip of Nova Scotia. Unfortunately, much of the soil is rocky and shallow in this area.

The largest tract of farm-land where actual evapotranspiration is over 23 inches is an area centering on London, Ontario. Around this is a much larger area enclosed by the 22 inch isopleth. It extends from Guelph to Lake St. Clair. Also in this 22-23 inch category is the St. Lawrence-Ottawa Lowland between Ottawa and Quebec City, the lower St. John Valley below Fredericton, and Nova Scotia west of Halifax.

The 20-22 inch range applies to Prince Edward Island and the remainder of Nova Scotia and New Brunswick except the central New Brunswick Uplands and Cape Breton Highlands. It covers the main body of southern Ontario, excluding the moister area already mentioned, and extends just to the Temiscaming Clay Belt and includes the Lakehead settlement and Rainy River district. In most of eastern Canada actual evapotranspiration is governed by heat rather than moisture.

No part of the Prairie Provinces is favoured with over 20 inches of actual evapotranspiration. The 18-20 inch actual evapotranspiration range applies to southern Manitoba although the Black Soils in this area will generally perform better than this criterion indicates. On the other hand the Northern Clay Belt of Ontario and Quebec, which also falls in this range fails to get the production that this criterion indicates. Similarly, the area southeast of the Regina plains is over-rated by this scheme. The lowlands of Newfoundland and the Gaspé peninsula fall in this range. All Saskatchewan is below the 18 inch isopleth and the only parts of Alberta above 18 inches are a small area in the foothills around Pincher Creek and a larger area farther north represented by Lacombe (18.1 inches), Springdale (18.5 inches), Calmar (19.2 inches), and Edson (19.2 inches).

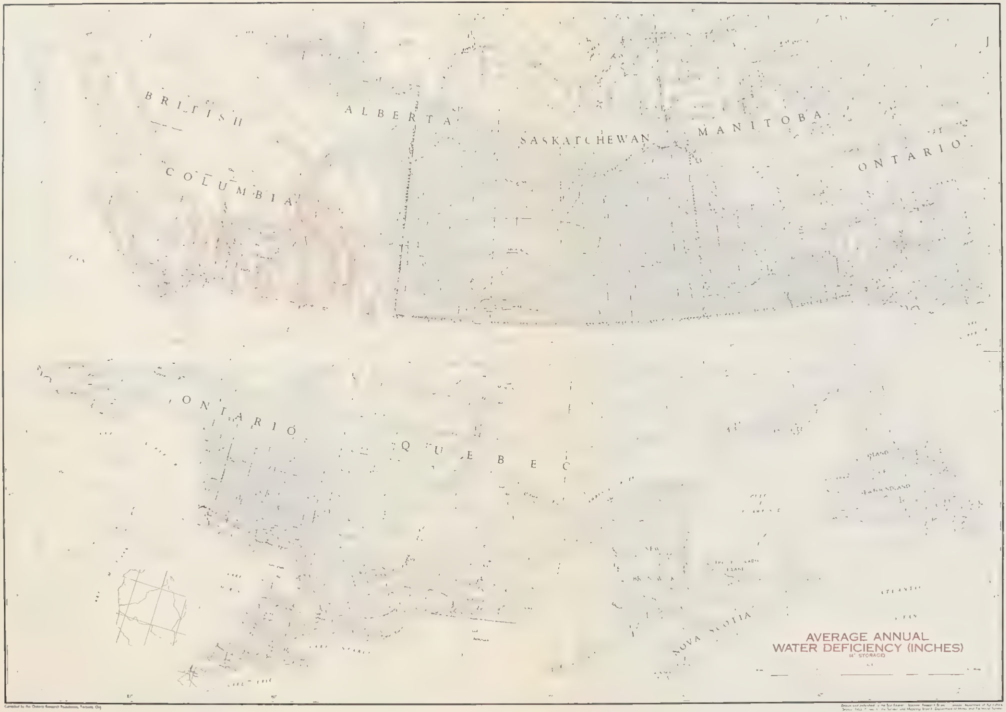
Actual evapotranspiration in Saskatchewan and Alberta amounts to 15-17 inches in the Black and Transitional Soil Zones and grades down to 12 inches in the driest parts of the Brown Soil Zone north, west and south of the Cypress Hills. The driest parts of the Okanagan and middle Fraser and Thompson Valleys, with under 10 inches, have the lowest rating by this criterion of any agricultural area in Canada, but with irrigation the full potential of over 25 inches may be realized.

It was mentioned earlier that north of latitude 50° there were no adjustments in Thornthwaite's potential evapotranspiration due to daylength, and it follows that this applies to actual evapotranspiration. However, actual evapotranspiration in the Prairie Provinces is limited by a deficiency of moisture and would not increase with an increase in potential evapotranspira-

FIGURE 19

AVERAGE ANNUAL WATER DEFICIENCY (INCHES)
(4″ STORAGE)

Water deficiency was computed, according to the Thornthwaite method (15) for all weather stations with temperature and precipitation records, comparing precipitation with water need (potential evapotranspiration) and assuming that soil holds 4 inches of water available for crops. In most cases potential evapotranspiration exceeds precipitation in summer. If it is not more than 4 inches greater than precipitation during the growing season there is no deficiency. It is assumed that evapotranspiration proceeds at the potential rate until the 4 inches of available soil moisture is used, then only precipitation is used until precipitation again exceeds potential evapotranspiration. During this period the difference between potential evapotranspiration and precipitation is computed as water deficiency. Average annual deficiency is zero over most of eastern Canada except for southern Ontario. It varies from 1 to 10 inches in the Prairie Provinces and from zero to 16 inches in British Columbia.



BRITISH
COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
ONTARIO
QUEBEC
NOVA SCOTIA
AVERAGE ANNUAL
WATER DEFICIENCY (INCHES)
(4" STORAGE)

FIGURE 20

AVERAGE ANNUAL ACTUAL EVAPOTRANSPIRATION (INCHES) (4″ STORAGE)

Actual evapotranspiration was computed according to the Thornthwaite method (15). Actual evapotranspiration is accumulated at the potential rate until the stored (4″) soil moisture is depleted, then it is governed by precipitation until this exceeds the potential rate when actual is the same as potential again. The total accumulated in this manner during the growing season is the annual actual evapotranspiration. Average annual actual evapotranspiration based on mean monthly temperatures and precipitation, varies from 10″ in the southern Okanagan Valley, British Columbia, to 23″ near London, Ontario.


BRITISH
COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
ONTARIO
QUEBEC
NOVA SCOTIA
AVERAGE ANNUAL ACTUAL
EVAPOTRANSPIRATION (INCHES)

tion. Therefore, for hay and pasture no premium should be given for the longer days in the north in this region.

It should be stressed again, that this criterion used a four-inch water holding capacity for soil throughout. Some soils hold less and others more than this amount. In the drier climates, where according to these computations the soil is not up to field capacity in the spring, a higher than four-inch moisture storage would not increase average actual evapotranspiration. Also, in the wet climates where the computed average deficiency is zero, actual evapotranspiration would not be increased by assuming a greater soil moisture storage. It might decrease with lower soil moisture holding capacity. However, in those moderately moist climates where the soil is at field capacity in the spring but deficiencies occur in summer, an increase in soil moisture above four inches would result in higher figures for actual evapotranspiration.

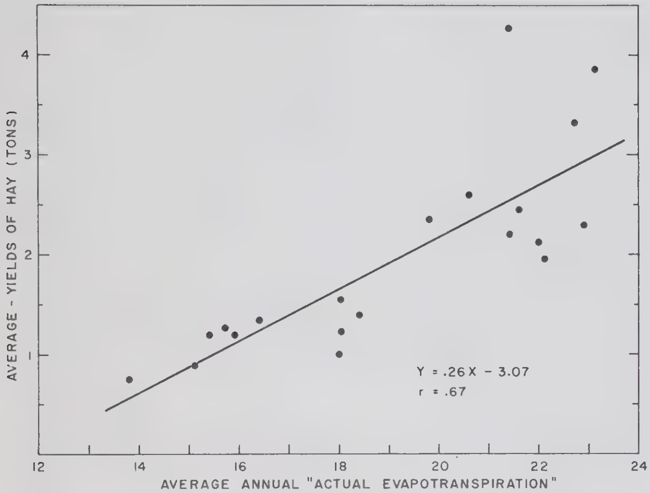


FIGURE 21: Relation between average annual hay yields at experiment stations across Canada and average actual evapotranspiration.

CLASSIFICATION

Up to this point the climate of the southern part of Canada has been analysed by means of ten maps dealing with temperature and the growing season, and six maps dealing with moisture. In order to synthesize, temperature and moisture classifications have been established. It was found that seven temperature zones were needed as shown in Figure 22. Similarly nine moisture classes have been adopted and outlined in Figure 23. By superimposing these two classifications a map of climatic regions was produced (Figure 24). As stated at the outset these were intended to show the main differences in climate important to field crops. More divisions might well be made for special crops. Even for field crops they are admittedly inadequate in the northern fringe areas of agriculture.

Temperature Zones

The seven temperature zones may be defined in terms of average number of degree-days (d.d.) above 42°F and average length of the frost-free (f.f.) period as follows:

1. Above 4,000 d.d.
2. 3,500 to 4,000 d.d.
3. 3,000 to 3,500 d.d.
4. 2,600 to 3,000 d.d.
5. 2,200 to 2,600 d.d. and 90+ f.f. days in Alberta and Saskatchewan.
6. 1,800 to 2,200 d.d. and 75 to 90 f.f. days in Alberta and Saskatchewan.
7. Less than 1,800 d.d. and less than 75 f.f. days in Alberta and Saskatchewan.

The first temperature zone distinguishes the cash-crop area in Essex and southern Kent Counties, Ontario, specialized to corn, soybeans, white beans, tobacco, winter wheat, sugar beets, tomatoes, cucumbers, sweet corn, early potatoes, lettuce, spinach, green beans, green peas, melons, peppers, asparagus, strawberries, raspberries, apples and peaches, to mention the most important crops. Early vegetables are a specialty and two crops are often grown in a season on the same land. The small areas of this class in British Columbia around Oliver, Osoyoos, Lillooet and Lytton unfortunately contain limited amounts of farmland.

The second temperature zone also refers to areas producing a wide range of crops. In British Columbia it covers the southern Okanagan Valley and in Ontario it includes the Niagara fruit belt, both of which have winters cold enough to induce dormancy in peaches but seldom falling below 12°F below zero, which has been taken as the lethal temperature for the fruit buds (7, 9). The main part of the lower Fraser and Thompson Valleys below Kamloops falls in this zone. Without this area, British Columbia would indeed be poor in agricultural resources.

The third zone in British Columbia occurs in a narrow belt around Zone 2 and extends northward along the coast over a forested area. The small area at Medicine Hat, Alberta, is on the 3,000 d.d. borderline and the area in southern Manitoba has only a little higher rating. By far the largest area of this zone is found in southern Ontario and Quebec. This area is characterized by livestock farms; cash-crop farms are not numerous outside of the tobacco districts. Zone 3 does not appear in the Maritime Provinces.

The number of crops grown in Zone 4 is much fewer than that grown in Zone 3 in Ontario. Some

silage corn is produced but the economy in eastern Canada is largely based on hay and pasture, oats and barley with potatoes, clover and grass seeds as specialties. In the Prairie Provinces, Zones 4 and 5 might well be grouped as the 2,600 d.d. line is not significant for wheat.

The 90-day frost-free line roughly corresponds to the 2,200 degree-day line. It is a well established limit for the southern edge of the moderate frost-hazard belt in Alberta and Saskatchewan and so was used in these two provinces, 2,200 degree-days being used elsewhere. It should be noted that the 90-day frost-free line does not always agree with agronomic experience; in the lower Saskatchewan Valley east of Prince Albert which is rated at over 90 days, frost damage is reputed to be common while in the Lacombe area in Alberta the frost hazard is reputedly low but the weather records place it well below the 90-day line. Similarly, 75 frost-free days were taken as the boundary between Zones 6 and 7 in Alberta and Saskatchewan. Frost hazard is severe for wheat and even oats and barley in Zone 7. Elsewhere this boundary is a compromise between 1,800 degree-days and 75 frost-free days. The shortness of the growing season and the occasional occurrence of summer frosts place severe restrictions on agriculture beyond Zone 6.

Moisture Classes

In order to recognize the important differences due to moisture, nine classes are needed in Canada as shown in Figure 23. From the driest to wettest they have been named C, D, E, F, G, H, K, L, M, the letters A and B being omitted because of an unwanted connotation of quality and I and J because these letters themselves are not distinctive. These classes, defined in terms of average water deficiency and average May to September precipitation are as follows:

Moisture Class	Water Deficiency (Inches)	May-Sept. Precipitation (Inches) Over 2,600 d.d.*	Under 2,600 d.d.*
C	Over 12	Under 6	—
D	12 - 9	6 - 8	—
E	9 - 7	8 - 11	8 - 9
F	7 - 5	10 - 12	9 - 11
G	5 - 3	12 - 13	10 - 13
H	3 - 1	13 - 15	12 - 15
K	1 - 0	15 - 16	14 - 18
L	0	—	16 - 20
M	0	—	Over 20

* d.d. = Degree-days above 42°F.

The first four of these classes (C, D, E, F) are dry climates and with minor exceptions relate to grasslands. They occur only in western Canada. Class G is one of fairly adequate moisture. It applies mainly to the aspen park-land belt in the Prairie Provinces and to the driest sections of southern Ontario. Crop failures due to droughts are rare in this class, but it should not be assumed that droughts never occur. Class H has the most nearly ideal moisture regime in Canada. Surplus water, causing delayed seeding and wet haying and harvesting conditions, becomes an important problem in the seventh, Class K, more than counter-balancing the lack of drought. In Class L, with its cool growing season, midsummer droughts are rare and wetness is a serious problem especially on clay soil. The last Class, M, takes in the wettest climate on the east and west coasts, where due to rocky shallow soil or steep mountain sides and snowy crests, very little agriculture is carried on. For forest the excess water in spring and fall is not as deleterious as for agriculture.

The driest class (C) comprises the valley floors in the southern interior of British Columbia. As mapped in Figure 23 the width of the areas is exaggerated. Without irrigation the only agriculture in these valleys is sparse grazing. In Class D, north, west and south of the Cypress Hills, the better clay lands are used for wheat, the remainder mostly for grazing. The same may be said of Class E, although with 8 to 9 inches of May to September precipitation, rather than 6 to 8 inches as in Class D, droughts tend to be less frequent and less severe (10). In the south, the boundary between Classes E and F coincides with the boundary between the Brown and Dark Brown Soils but towards the north it extends across the Brown Soil Zone. Similarly, Moisture Class F coincides with the Brown Soil Zone in the south and the Black Soil Zone in the north, even encroaching on the Transitional Soils in the Prince Albert area. The section of the Black Soil Zone falling within Moisture Class F contains large areas of thin Black Soils, so called because of the relatively thin A_h horizons in their profiles.

Class G lies between the 5- and 3-inch deficiency lines. It contains the remainder of the Black Soil Zone except the moist fringe between Lacombe, Alberta, and the U.S.A. border. Class G contains most of the Transitional Soils and also covers a broad area of Gray Wooded Soils. This class includes most of the Peace River district, extends across the Prairie Provinces and reappears in southwestern Ontario (Figure 23). The average annual water deficiency computed for Beaverlodge is 4.6 inches, Edmonton 4.3 inches, Morden 4.3 inches and Chatham 4.2 inches. In Manitoba this class covers the settled area with the moisture status increasing from west to east. The Riding and Duck Mountains are exceptions, and the higher moisture status is sufficient to have them indicated as a higher moisture class.

Class H has the most favourable moisture regime of any of these classes and crop failures due to drought seldom occur. However, the browning-off of pastures

FIGURE 22

TEMPERATURE ZONES

These temperature zones are based on degree-days (d.d.) above 42°F and the frost-free (f.f.) period. The agricultural areas of Canada have been divided into temperature zones as follows:

1. Above 4,000 d.d.
2. 3,500 to 4,000 d.d.
3. 3,000 to 3,500 d.d.
4. 2,600 to 3,000 d.d.
5. 2,200 to 2,600 d.d. and
   90+ f.f. days in Alberta and Saskatchewan
6. 1,800 to 2,200 d.d. and
   75 to 90 f.f. days in Alberta and Saskatchewan
7. Less than 1,800 d.d. and
   less than 75 f.f. days in Alberta and Saskatchewan

In British Columbia zones were combined for readability and the widths of the valley zones are exaggerated unavoidably. All seven zones occur in British Columbia and Ontario, Zones 3 to 7 on the Prairies and Quebec, 4 to 7 in the Maritimes and 6 and 7 in Newfoundland.

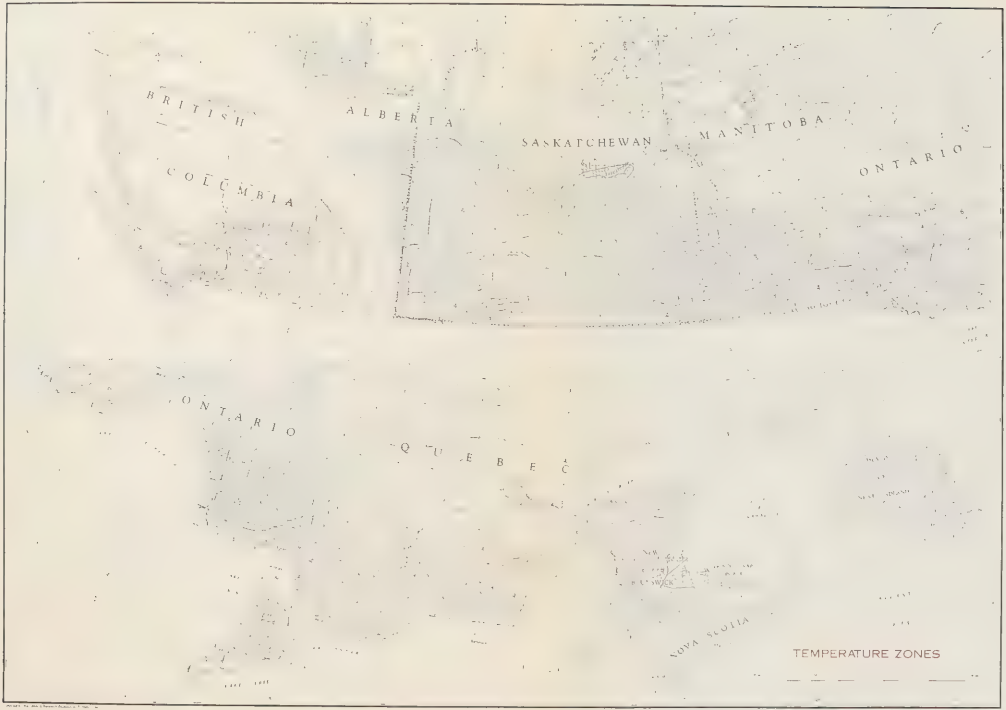

BRITISH COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
ONTARIO
QUEBEC
NOVA SCOTIA
TEMPERATURE ZONES

FIGURE 23

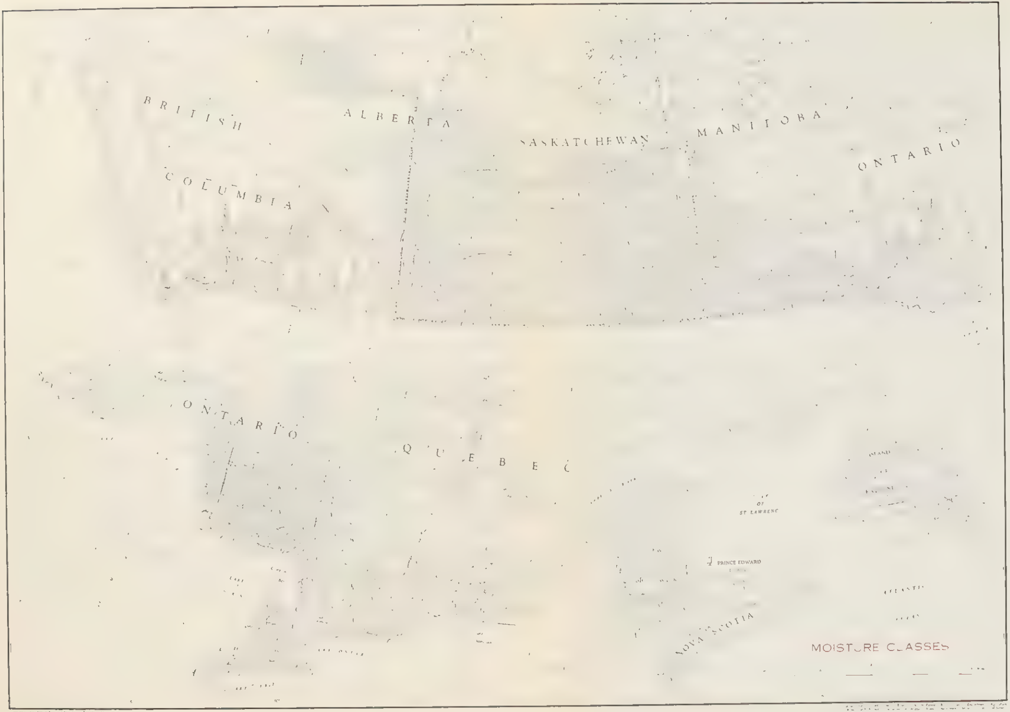
MOISTURE CLASSES

These moisture classes are based on average water deficiency and average May to September precipitation. The agricultural areas of Canada have been divided into moisture classes as follows:

Class	Water deficiency (inches)	May-Sept. precipitation (inches) Over 2600 d.d.*	Under 2600 d.d.*
C	Over 12	Under 6	-
D	12 - 9	6 - 8	-
E	9 - 7	8 - 11	8 - 9
F	7 - 5	10 - 12	9 - 11
G	5 - 3	12 - 13	10 - 13
H	3 - 1	13 - 15	12 - 15
K	1 - 0	15 - 16	14 - 18
L	0	-	16 - 20
M	0	-	over 20

* d.d. = Degree-days above 42°F.

Classes in British Columbia were combined for readability and illustration, with the extent of the valley classes exaggerated unavoidably. All nine classes occur in British Columbia, Classes D to L on the Prairies, only the four from G to L in Ontario, three (H, K, L) in Quebec, three (K, L, M) in the Maritimes and two (L, M) in Newfoundland.


BRITISH COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
ONTARIO
QUEBEC
OF ST LAWRENCE
PRINCE EDWARD
NOVA SCOTIA
MOISTURE CLASSES

in midsummer is usual and supplemental irrigation on tobacco and some fruit and vegetable crops is standard practice. This class covers most of southern Ontario and the lowland around Montreal in Quebec Province. It also takes in the Kenora-Dryden area in northwestern Ontario and a strip lying along the Ontario-Manitoba border. As pointed out by Sanderson (13), Kenora with low winter and high summer precipitation has the most nearly ideal moisture regime for agriculture of any station in Canada.

Class K, with average moisture deficiency between one and zero inch and May to September precipitation ranging from 14-18 inches, was separated from wetter climates because surplus water and muddy soil conditions are not yet serious in this class. In Class L, surplus moisture is a major problem especially on poorly drained clay land which predominates in the settled areas of northern Ontario and Quebec. Much of the agricultural parts of the Atlantic Provinces falls into the latter class, the exceptions mapped as Class K, being Prince Edward Island and the coastal area along Northumberland Strait, the Annapolis Valley and part of the St. John Valley, above and below Fredericton, New Brunswick.

The wettest class, in which May to September precipitation exceeds 20 inches, is found along the south coasts of Nova Scotia and Newfoundland and on the slopes facing the Pacific Ocean. This class is shown in generalized fashion in Figure 23.

Climatic Regions

By combining seven temperature zones with nine moisture classes, sixty-three climatic regions are possible. In southern Canada, warm-moist regions or cool-dry regions are not found. The agricultural areas are covered by 40 regions and some of these apply to areas mostly in forest. The climatic regions outlined by combining the temperature zones and moisture classes, with slight changes of boundaries to eliminate small areas, are shown in Figure 24. In British Columbia the mountain areas were left unmapped, only the valleys and coastal plains being dealt with as these are the only areas with weather records and they include nearly all the agriculture.

The various temperature and moisture combinations mapped are listed below.

1.	C,				G				
2.	C,			F,	G,	H			
3.	C,	D,	E,	F,	G,	H,	K,	L,	M
4.	C,	D,	E,	F,	G,	H,	K,	L,	M
5.			E,	F,	G,	H,	K,	L,	M
6.			E,	F,	G,	H,	K,	L,	M
7.					G,	H			

The warm-wet and cool-dry climates are absent in the southern part of Canada. There are also some dry classes missing in Temperature Zones 1 and 2, but the 1D and 2D climates probably occur on the fringe of the 1C and 2C areas in the valleys of southern British Columbia. Some of the cooler, moister climates apply to areas mostly in forest.

In many cases, widely separated areas have the same regional climate and these areas often have different winter conditions which might be used as a basis for sub-division. In order to draw attention to these similar climatic regions, and to define them in terms of all the criteria used in this study, a summary table has been prepared (Table 1).

The occurrence of similar climate regions in separate parts of the country is of interest to agriculturists and this classification identifies several that should be mentioned. In most cases points of difference appear when winter temperatures and other factors are considered. For instance, the Niagara Peninsula and a section of the Fraser Valley near Hope are both classed as 2G but the latter area has much warmer winters and a longer, cooler growing season. The Georgian Bay shore and Renfrew districts of Ontario, and the southern Manitoba area around Morden and Morris fall in the 3G Region. January normal temperatures in these three areas are about 20°, 12° and 2°F, respectively. The Georgian Bay area receives about twice as much snowfall as the Morden-Morris area. The several climatic regions of type 4K, described in Table 1, from Rainy River to Prince Edward Island are well adapted to potato growing. The Annapolis Valley, also classed as 4K, is more adapted to apple production because of more moderate winters than any of the other areas of this type.

Region 1G and the Niagara fruit belt in 2G have the most versatile climates found in Canada. The Essex-Kent area has the advantage of early springs and the Niagara fruit belt has mild winters. The 1-2C Regions in British Columbia, where irrigated, must be included in this category also. It seems that the best moisture conditions are found in Class H.

Under moist conditions, as in all of eastern Canada, the successive temperature zones have decreasing potential, Zones 6 and 7 particularly being under a severe handicap. Under the relatively dry conditions of the southern Prairies the warmer conditions of Zone 4 are a detriment rather than an advantage. For wheat and other grains the moisture Class G is the best there is in the Prairies (5, 14). Therefore, the four drier classes must be rated progressively downward.

For the general farming prevailing in most of eastern Canada, Moisture Class K is close to H in the south, but has to be rated lower in the northern areas such

as the Temiscaming Clay Belt. Region 6L must be rated below Region 6K in the Clay Belts of northern Ontario and Quebec. The Peace River district, the majority of which is in the 6G Climatic Region, is a wheat, oats and barley growing area, whereas the clay belts in the east are not. No doubt this is mostly due to the handicap imposed by wetness at seeding and harvest time in Regions 6K and 6L, mentioned earlier, although the longer days in the Peace River area probably help in hastening the maturity of these cereals (3). In Climatic Regions 6M, 7L and 7M the higher moisture regimes must also be rated down for agriculture. This may not apply in relation to forests which occupy nearly all of these cool, wet regions.

FIGURE 24

CLIMATIC REGIONS FOR AGRICULTURE

This map was prepared by superimposing the temperature and moisture maps and combining the two into climatic regions. A smoothing and combining process left out a few narrow regions and small "pockets" created by closely parallel and crossing boundaries, respectively. Several of the boundaries were omitted in British Columbia in the non-agricultural areas. The combination of temperature zones and moisture classes in the Prairie Provinces created many climatic regions as they tend to run perpendicular to each other. A similar situation occurs north of London in southwestern Ontario. In other areas moisture class boundaries ran half-way between and parallel to temperature zone boundaries creating two or more regions. Consequently the agricultural areas of Canada have been divided into 40 climatic regions, as listed in Table 1.

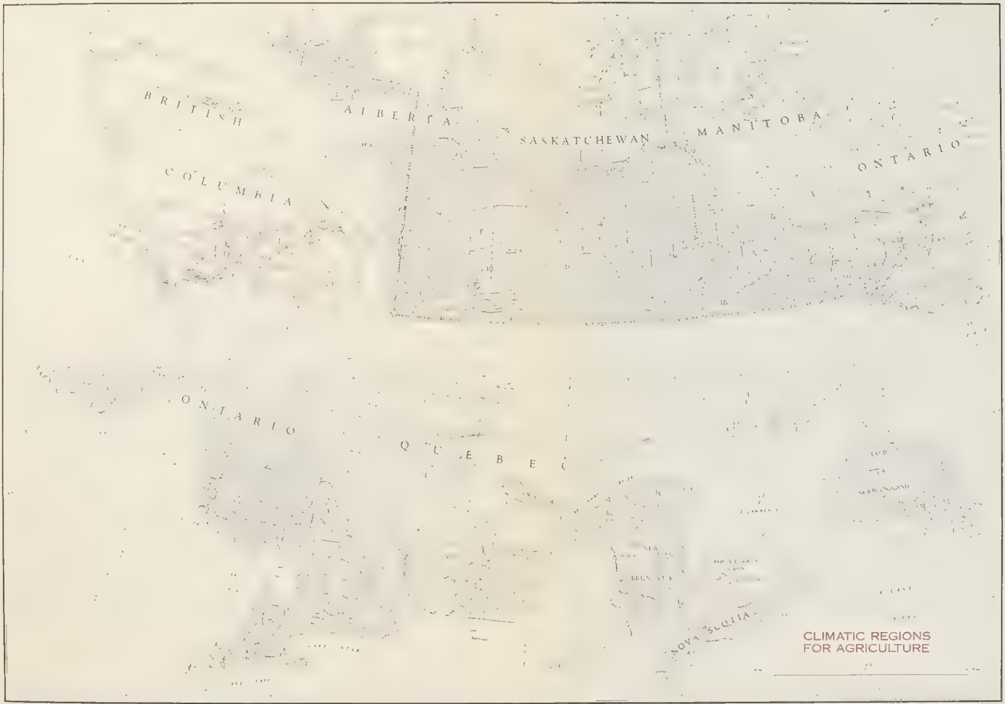

BRITISH
COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
ONTARIO
QUEBEC
NOVA SCOTIA
CLIMATIC REGIONS
FOR AGRICULTURE

TABLE 1.

Regional Climates of Southern Canada
(Average Data)

CLASS	REGION	DEGREE-DAYS ABOVE 42°	POTENTIAL E.T. (INCHES)	CORN HEAT UNITS	GROWING SEASON START	END
1 G	Essex and South Kent	4,200	26	3,400	April 3	Nov. 10
1.2 C	Southern Okanagan Valley	3,800	26	3,000	March 20	Oct. 31
2 C	Middle Fraser - Lower Thompson	3,750	26	3,000	March 20	Oct. 31
2 F	Hope, B.C.	3,600	25	2,700	March 10	Nov. 5
2 G	Niagara Fruit Belt	3,950	25	3,300	April 10	Nov. 10
	North Kent County	3,950	25	3,250	April 6	Nov. 8
	Lake Erie	3,800	24.5	3,200	April 10	Nov. 8
	North Shore Lake Ontario	3,600	24	3,000	April 15	Nov. 3
2 G.H	Lower Fraser Valley	3,600	25.5	2,750	March 2	Nov. 20
2 H	Sarnia - Niagara Peninsula	3,600	24	3,000	April 9	Nov. 5
3.4 C	Lillooet, B.C.	3,000	26	2,300	March 20	Oct. 31
	Middle Thompson River	3,000	24	2,300	March 31	Oct. 20
	Nicola - Shuswap	2,900	24	2,300	March 31	Oct. 20
	Okanagan Lake	3,300	25	2,700	March 25	Oct. 25
3 D	Medicine Hat, Alta.	3,200	24	2,300	April 10	Oct. 20
3.4 D	Armstrong - Salmon Arm, B.C.	3,000	24	2,250	March 31	Oct. 25
3.4 D.E	Southeast Vancouver Is.	3,200	25.5	2,600	March 10	Nov. 25
3.4 E.F	Abbotsford, B.C.	3,200	25.5	2,500	March 10	Nov. 15
3 G	Morden - Morris, Man.	3,100	23	2,300	April 20	Oct. 16
	Georgian Bay Shore	3,200	22.5	2,500	April 20	Oct. 31
	Renfrew, Ont.	3,100	22.5	2,300	April 20	Oct. 23
3 H	Lake Huron Slopes	3,200	23	2,700	April 17	Oct. 31
	Guelph, Ont.	3,300	23	2,700	April 15	Oct. 30
	South Central Ontario	3,300	23	2,600	April 15	Oct. 28
	Eastern Ontario	3,300	23	2,600	April 15	Oct. 28
	Gatineau Hills	3,200	23	2,400	April 20	Oct. 25
	Montreal, P.Q.	3,400	23	2,700	April 17	Oct. 28
3 K	London - Listowel, Ont.	3,300	23	2,700	April 15	Oct. 28
	North of Lake Champlain	3,300	23	2,600	April 17	Oct. 25
3 L	Drummondville, P.Q.	3,100	22.5	2,400	April 20	Oct. 23
4 C	Newgate, B.C.	2,800	24	—	April 5	Oct. 20
4 D	Sand Hills - Alta. and Sask.	2,800	22.5	2,000	April 15	Oct. 18
	Alta. - Sask. - U.S. Border	2,900	22.5	1,900	April 15	Oct. 18
4 D.E	Lillooet Lake	2,900	25	2,250	March 30	Oct. 25
	Lower Arrow Lake	2,750	24	2,350	April 5	Oct. 20
	West Kootenay Basin	2,800	23.5	2,100	April 5	Oct. 20
4 E	Taber, Alta.	2,800	22.5	2,000	April 15	Oct. 20
	South Central Saskatchewan	2,750	22.5	1,900	April 20	Oct. 13

FROST SEASON (32°F) SPRING	FALL	PERIOD	MEAN TEMPERATURES (°F) ANNUAL MIN.	JAN.	JULY	MOISTURE (INCHES) DEFIC.	MAY-SEPT. PPTN.	ANNUAL PPTN.	ACTUAL E.T.	CLASS
May 3	Oct. 18	170	—2	26	73	4	13	30	21.5	1 G
May 1	Oct. 5	160	—5	25	70	16	4	11	11	1.2 C
April 25	Oct. 15	170	—10	24	71	16	4	12	11	2 C
April 15	Oct. 31	200	3	32	64	5	11	55	20	2 F
May 1	Oct. 20	170	—1	26	70	3.5	13	30	21	2 G
May 8	Oct. 15	160	—5	24	72	3.5	14	32	22	
May 10	Oct. 12	155	—7	25	71	3	14	34	21.5	
May 10	Oct. 5	150	—15	21	70	4	13	32	20	
April 15	Oct. 31	200	12	35	64	2	14	60	23	2 G.H
May 12	Oct. 10	150	—10	24	70	2	15	35	22	2 H
May 5	Oct. 5	150	—10	24	68	14	5	13	12	3.4 C
May 20	Sept. 20	125	—20	19	65	10	6	16	14	
May 20	Sept. 20	125	—20	20	65	13	5	12	11	
May 5	Oct. 1	150	—5	26	69	13	5	12	11	
May 15	Sept. 15	125	—34	14	70	10	8	14	13.5	3 D
May 15	Sept. 20	130	—15	24	68	11	7	18	13	3.4 D
April 10	Nov. 10	215	20	38	62	9	6	35	16	3.4 D.E
April 20	Oct. 20	185	10	36	63	5	10	50	20	3.4 E.F
May 21	Sept. 15	115	—35	2	69	4.5	12	20	18	3 G
May 16	Oct. 5	140	—10	20	67	3	13	32	20	
May 18	Sept. 22	125	—30	12	67	3	13	29	20	
May 16	Oct. 5	140	—15	21	67	2	14	34	21	3 H
May 16	Sept. 30	135	—15	20	68	2	15	31	21	
May 15	Sept. 30	135	—20	18	69	2	14	31	20.5	
May 13	Sept. 30	140	—25	14	69	2	15	35	21	
May 16	Sept. 20	130	—28	11	68	2	15	37	21	
May 10	Sept. 30	145	—20	14	69	1	16	37	22	
May 18	Sept. 30	135	—15	21	68	0.5	16	37	22.5	3 K
May 13	Sept. 28	135	—25	13	69	0.5	17	38	22.5	
May 17	Sept. 23	125	—25	12	68	0	19	42	22.5	3 L
June 1	Sept. 5	95	—24	20	65	13	6	14	11.5	4 C
May 25	Sept. 10	110	—39	10	68	10	7.5	13	12.5	4 D
May 25	Sept. 10	110	—35	10	68	10	7	12	12	
May 15	Oct. 5	145	—20	23	65	10	7	36	15	4 D.E
May 15	Oct. 1	140	—7	22	67	9	7	20	15	
May 15	Sept. 25	135	—7	24	66	9	7	25	15	
May 17	Sept. 17	125	—30	15	67	8	9	14	13.5	4 E
May 30	Sept. 10	105	—37	6	67	8	9	14	13.5	

CLASS	REGION	DEGREE-DAYS ABOVE 42°	POTENTIAL E.T. (INCHES)	CORN HEAT UNITS	GROWING SEASON START	END
4 F	Upper Arrow Lake	2,950	23.5	—	April 5	Oct. 25
	Lethbridge, Alta.	2,750	23	2,000	April 15	Oct. 20
	Weyburn - Estevan, Sask.	2,750	22	1,950	April 20	Oct. 13
4 F.G	East Vancouver Island	2,900	25	2,000	March 20	Nov. 15
4 G	Southern Manitoba	2,800	22.5	2,150	April 22	Oct. 13
	Manitoulin Island	2,850	21.5	2,300	April 25	Oct. 31
	Bruce Peninsula	2,950	22.5	2,500	April 22	Nov. 1
4 H	Sayward District, B.C.	2,700	24	—	March 25	Nov. 15
	Sudbury, Ont.	2,800	21.5	2,100	April 25	Oct. 21
	Nipissing - Kawartha Lakes	2,900	22	2,250	April 21	Oct. 22
	Gatineau Valley	2,900	22	2,100	April 22	Oct. 21
4 K	Dundalk Upland	2,800	21.5	2,300	April 22	Oct. 26
	North Bay - Haliburton, Ont.	2,700	21	2,000	April 24	Oct. 20
	Middle Ottawa River	2,700	21	2,000	April 24	Oct. 19
	Gatineau - Shawinigan, P.Q.	2,800	22	2,100	April 23	Oct. 18
	Middle St. John Valley	2,800	22	2,200	April 23	Oct. 23
	Annapolis Valley	2,950	22	2,200	April 20	Nov. 2
	Northumberland Shore	2,700	21.5	2,100	April 27	Oct. 28
	Prince Edward Island	2,750	22	2,250	April 30	Oct. 31
4 L	St. Maurice River - Isle d'Orleans	2,800	21.5	2,200	April 22	Oct. 18
	Isle d'Orleans - Sherbrooke	2,800	21.5	2,200	April 22	Oct. 21
	Southwest New Brunswick	2,700	21	2,000	April 22	Oct. 25
	Chaleur Bay - Bay of Fundy	2,700	21.5	2,000	April 25	Oct. 23
	Nova Scotia Interior	2,700	21	1,900	April 22	Oct. 31
4 H.K.L	Rainy River District	2,750	22	2,000	April 25	Oct. 16
4 M	Ocean Falls, B.C.	2,800	24	—	March 25	Nov. 10
	South Shore of Nova Scotia	2,800	22	2,100	April 30	Nov. 5
5 D	East Kootenay Basin	2,400	21.5	—	April 15	Oct. 10
5 E	Hanna - Saskatoon, Sask.	2,400	21	1,750	April 21	Oct. 11
	Cypress Hills Slopes	2,400	22	1,800	April 20	Oct. 15
5.6 E	Golden, B.C.	2,500	22	—	April 15	Oct. 15
5 F	Viking - Vulcan, Alta.	2,400	21	1,600	April 22	Oct. 13
	Prince Albert - Indian Head, Sask.	2,400	21	1,650	April 25	Oct. 11
5 G	Cardston, Alta.	2,400	21.5	1,500	April 20	Oct. 17
	Edmonton, Alta.	2,150	21	—	April 21	Oct. 9
	Yorkton - Carlyle, Sask.	2,400	21	1,650	April 26	Oct. 11
	Interlake - Manitoba	2,400	21	1,800	April 30	Oct. 10
5 K	Temiscaming	2,500	20.5	1,700	April 30	Oct. 16
	Algonquin Park	2,550	21	1,900	April 27	Oct. 18

FROST SEASON (32°F) SPRING	FALL	PERIOD	MEAN TEMPERATURES (°F) ANNUAL MIN.	JAN.	JULY	MOISTURE (INCHES) DEFIC.	MAY-SEPT. PPTN.	ANNUAL PPTN.	ACTUAL E.T.	CLASS
June 1	Sept. 1	90	—12	22	66	6	9	30	17	4 F
May 18	Sept. 17	120	—30	18	66	6	9.5	17	16.5	
May 30	Sept. 6	100	—37	4	67	6	10	16	15.5	
May 1	Nov. 1	185	12	35	63	5	9	55	20	4 F.G
May 25	Sept. 12	110	—37	2	67	4	12	19	18	4 G
May 28	Sept. 30	125	—25	17	67	3	12	32	18	
May 22	Oct. 10	140	—10	21	67	3	13	33	20	
May 1	Nov. 1	185	12	35	62	4	10	60	20	4 H
May 30	Sept. 22	115	—30	12	66	2	15	33	20	
May 23	Sept. 22	120	—30	13	67	2	15	35	20	
May 20	Sept. 17	120	—35	10	67	2	15	33	20.5	
May 25	Sept. 20	120	—25	18	66	0.5	14	37	21	4 K
May 28	Sept. 16	110	—35	13	66	0.5	15.5	36	21	
May 26	Sept. 16	115	—35	10	66	0.5	14	31	20	
May 20	Sept. 17	120	—35	9	66	0	17	35	21.5	
May 25	Sept. 23	120	—20	14	67	0.5	15	39	22	
May 24	Sept. 30	130	—10	22	66	0.5	16	41	22	
May 25	Sept. 30	130	—15	18	65	0.5	15	38	21	
May 22	Oct. 5	135	—10	18	66	0.5	16	42	21.5	
May 20	Sept. 17	120	—35	8	66	0	19	40	21.5	4 L
May 20	Sept. 20	120	—25	12	66	0	20	42	21.5	
May 22	Sept. 22	125	—15	17	65	0	17	43	21	
May 28	Sept. 18	115	—25	14	66	0	16	38	21.5	
May 28	Sept. 25	120	—15	21	65	0	17.5	48	21	
May 28	Sept. 15	110	—43	1	67	0	15	26	22	4 H.K.L
April 10	Nov. 1	205	12	34	61	0	45	175	24	4 M
May 20	Sept. 30	130	—5	25	62	0	>20	55	22	
June 1	Sept. 1	90	—30	13	64	10	7	14	11	5 D
May 31	Sept. 2	95	—37	7	65	8	8	13	12.5	5 E
May 31	Sept. 1	95	—36	10	66	8	8.5	14	13.5	
June 5	Aug. 25	80	—30	12	64	9	7	18	13	5.6 E
May 31	Sept. 5	100	—35	9	63	6	9.5	15	14.5	5 F
June 1	Sept. 5	95	—43	0	65	6	9.5	15	14.5	
May 25	Sept. 11	110	—29	20	64	4	11	19	17.5	5 G
June 2	Aug. 31	90	—35	6	63	4	11	17	16.5	
June 3	Sept. 5	95	—42	0	65	4	11	17	16.5	
May 25	Sept. 13	110	—42	—3	66	4	11	20	16.5	
June 1	Sept. 12	100	—35	10	64	0.5	15	31	20	5 K
June 1	Sept. 10	100	—35	11	64	1	13.5	31	20	

CLASS	REGION	DEGREE-DAYS ABOVE 42°	POTENTIAL E.T. (INCHES)	CORN HEAT UNITS	GROWING SEASON START		GROWING SEASON END	
5 L	Lakehead	2,400	20.5	1,900	April	28	Oct.	15
	Montagne Tremblante	2,500	20.5	2,000	April	26	Oct.	15
	Lake St. John	2,400	20.5	1,900	May	2	Oct.	13
	Maine Border	2,550	20.5	1,950	April	26	Oct.	16
	Eastern Slopes of New Brunswick	2,500	20.5	1,800	April	28	Oct.	16
	Cape Breton	2,500	21	2,000	April	30	Oct.	30
5.6 M	Bella Coola, B.C.	2,500	23	—	March	31	Oct.	25
	Prince Rupert, B.C.	2,100	24	—	April	5	Oct.	31
6 E	Cypress Hills	2,000	21	—	April	25	Oct.	10
6 F	Fort Vermilion, Alta.	1,900	19	—	May	2	Sept.	28
6 F.G	Smithers, B.C.	1,800	19	—	April	20	Oct.	5
	Vanderhoof, B.C.	1,800	19	—	April	30	Oct.	5
6 G	Calgary, Alta.	2,000	20.5	—	May	23	Oct.	12
	Sion - Vermilion, Alta.	2,050	20.5	—	May	23	Oct.	6
	Central Peace River	2,050	20.5	—	May	25	Oct.	7
	East Central Saskatchewan	2,100	20	—	May	30	Oct.	6
	Lake Winnipeg North	2,000	19	—	May	5	Oct.	6
6 H	Prince George, B.C.	2,000	19	—	April	20	Oct.	5
	Lacombe, Alta.	2,000	20	—	April	23	Oct.	10
	Southern Fringe Peace River	2,000	20	—	April	26	Oct.	6
6 H.K	Pincher Creek, Alta.	2,050	20	—	April	25	Oct.	14
	Middle Kenora	2,000	19	—	May	10	Oct.	5
6 K	Height of Land - Northern Ontario	2,150	19.5	—	May	3	Oct.	8
6 L	Northern Clay Belts	2,100	19.5	—	May	5	Oct.	10
	Parc de Laurentides	<2,000	19	—	May	5	Oct.	10
	Anticosti Island	<1,500	18	—	May	12	Oct.	13
	Gaspé Shore	2,000	19.5	—	May	8	Oct.	15
	Uplands of New Brunswick	2,000	19	—	May	2	Oct.	10
	Central Newfoundland	1,900	19	—	May	10	Oct.	21
6 M	Southern Newfoundland	1,900	19.5	—	May	15	Oct.	30
7 G	Peace River Fringe	1,750	20	—	April	28	Oct.	5
	Northern Settled Fringe - Sask.	1,900	20	—	May	1	Oct.	1
7 H.K	Athabaska River	1,800	19	—	April	30	Oct.	5
7 L	Moosonee - Strait of Belle Isle	<1,800	<18	—	May	15	Oct.	5
	Northern Newfoundland	<1,800	<19	—	May	10	Oct.	10
	Central Gaspé	<1,800	<19	—	May	15	Oct.	10

FROST SEASON (32°F)			MEAN TEMPERATURES (°F)			MOISTURE (INCHES)				
SPRING	FALL	PERIOD	ANNUAL MIN.	JAN.	JULY	DEFIC.	MAY-SEPT. PPTN.	ANNUAL PPTN.	ACTUAL E.T.	CLASS
June 5	Sept. 5	90	—35	6	64	0	15	27	20.5	5 L
May 30	Sept. 12	105	—38	7	64	0	18	37	20.5	
June 3	Sept. 12	100	—33	2	64	0	18	32	20.5	
May 30	Sept. 16	110	—30	10	64	0	17.5	37	20.5	
June 1	Sept. 12	105	—28	10	65	0	17	38	20.5	
May 30	Sept. 25	115	—10	20	64	0	19	50	21	
May 10	Oct. 1	145	0	29	61	0	14	63	23	5.6 M
April 20	Nov. 1	195	10	35	56	0	27	94	24	
June 15	Aug. 25	70	—37	8	62	7	10	17	14	6 E
June 3	Aug. 17	65	—50	—9	62	6.5	8	13	12	6 F
June 15	Aug. 31	75	—25	16	58	5	8	18	14	6 F.G
June 25	Aug. 20	55	—35	12	57	7	7	17	12	
June 3	Sept. 5	95	—35	11	62	4	11	17	16.5	6 G
June 7	Aug. 25	80	—42	6	62	4	10.5	17	16.5	
June 5	Sept. 1	85	—40	5	61	4.5	10	17	15.5	
June 7	Sept. 2	85	—45	—4	64	4	10.5	17	16	
May 31	Sept. 10	100	—42	—6	65	4	10.5	18	15	
June 15	Aug. 25	70	—38	15	60	3	11	25	16	6 H
June 2	Aug. 31	90	—38	9	61	2	12	18	17.5	
June 15	Aug. 25	70	—42	5	60	3	11	18	16.5	
June 5	Sept. 5	90	—31	18	60	2	12	21	18	6 H.K
June 10	Sept. 5	85	—40	—7	64	1	14	22	18	
June 10	Aug. 31	80	—40	2	62	0.5	14	30	19	6 K
June 10	Sept. 3	85	—43	0	63	0	17	33	19.5	6 L
June 8	Sept. 10	95	—40	7	60	0	20	40	19	
June 5	Sept. 15	100	—15	10	59	0	13	31	18	
June 2	Sept. 15	105	—15	11	61	0	14	35	19.5	
June 5	Sept. 10	95	—30	5	63	0	18	40	19	
June 15	Sept. 20	100	—15	18	61	0	16	40	19	
June 8	Sept. 25	110	—5	23	58	0	>20	50	19.5	6 M
June 15	Aug. 25	70	—42	4	60	4	11	18	16	7 G
June 20	Aug. 20	60	—48	—3	61	4.5	10	16	15	
June 15	Aug. 15	60	—48	0	60	3	12	18	16	7 H.K
June 15	Aug. 31	75	—45	—5	59	0	17	29	<18	7 L
June 8	Sept. 3	85	—35	5	60	0	18	37	<19	
June 15	Sept. 15	90	—15	15	57	0	16	35	<19	

REFERENCES

1. Albright, W. D. and J. G. Stoker. Topography and minimum temperature. Sci. Agr. 25: 40-51. 1944.

2. Boughner, C. C., R. W. Longley, and M. K. Thomas. Climatic Summaries, Vol. III, Frost Data. Met. Div., Can. Dept. of Transport, Toronto, Ont. 1956.

3. Carder, A. C. Growth and development of some field crops, as influenced by climatic phenomena at two diverse latitudes. Can. J. Plant Sci. 37: 392-406. 1957.

4. Carder, A. C. Northwestern Canada's climate: its effect on crop growth and development. Agr. Inst. Rev. May-June, 1965.

5. Garland, S. W. and T. O. Riecken. A general classification of land for agricultural use by townships, Manitoba. Economics Div., Can. Dept. Agr. and Manitoba Dept. of Agr. and Cons., Winnipeg, Man. 1963.

6. Hutcheon, W. L., J. S. Clayton, C. J. Acton, and W. Houston. Guidelines to soil capability classification in Saskatchewan. Dept. of Soil Science, U. of Saskatchewan, Saskatoon, Sask. 1964.

7. Krueger, R. R. The physical basis of the orchard industry of British Columbia. Geog. Bull. 20: 5-38. 1963.

8. Laycock, A. H. Moisture in the Prairie Provinces. Report prepared for Prairie Farm Rehabilitation Act. Motherwell Building, Regina, Sask. 1964.

9. Mercier, R. G., and L. J. Chapman. Peach climate in Ontario. 1955-56 Report of the Horticultural Experiment Station and Products Laboratory, Vineland, Ont.

10. Moss, H. C. The relation between type of soil and yields of wheat in Saskatchewan. Dept. of Soil Science, U. of Saskatchewan, Saskatoon, Sask. 1962.

11. Putnam, D. F., and L. J. Chapman. The climate of Southern Ontario. Sci. Agr. 18: 401-446. 1938.

12. Robertson, G. W. Estimating hay yields from climatic data. Soil Horizons, 4: 25-26. Can. Dept. Agr., Ottawa. 1963.

13. Sanderson, Marie. The climates of Canada according to the new Thornthwaite classification. Sci. Agr. 28: 501-517. 1948.

14. Scott, H. K. A study of crop yields in Alberta. Economics Div., Can. Dept. Agr., Ottawa, 1958.

15. Thornthwaite, C. W. An approach toward a rational classification of climate. Geog. Rev. 38: 55-94. 1948.

16. Valle, Otto and A. C. Carder. Comparison of the climate at Tikkurila, Finland and at Beaverlodge, Alberta, Canada with particular reference to the growth and development of cereal crops. Acta Agralia Fennica, 100: 1-31. 1962.

BIBLIOGRAPHY

Anstey, T. H., G. M. Weiss, A. W. Watt, J. C. Wilcox, and P. N. Sprout. Relation of soil, temperature and topography to fruit growing in Summerland, B.C. Can. J. Plant Sci. 39: 297-315. 1950.

Clayton, J. S. and J. G. Ellis. Soil survey of the experimental stations and substations of the Canada Department of Agriculture in Saskatchewan. Dept. of Soil Science, U. of Saskatchewan, Saskatoon, Sask. 1964.

Craigie, J. H. Epidemiology of stem rust in western Canada. Sci. Agric. 25: 285-401. 1945.

Dermine, P. Weather of the growing season in the Clay Belt. Can. Dept. Agr. Pub. 1234. 1965.

Freeman, T. H. The Saskatchewan rural land assessment system. Dept. of Municipal Affairs, Regina, Sask. 1950.

Johnson, L. M. and T. O. Riecken. Manitoba farm land values. Economics Div., Can. Dept. Agr., Winnipeg, Man. 1964.

Kendrew, W. G. and B. W. Currie. The climate of central Canada. Queen's Printer, Ottawa, 1955.

Kendrew, W. G. and D. Kerr. The climate of British Columbia and the Yukon Territory. Queen's Printer, Ottawa, 1955.

Krueger, R. R. The geography of the orchard industry of Canada. Geog. Bull. 7: 27-71. 1965.

Lovering, J. H. Agricultural land use in the Fort Vermilion-La Crete area of Alberta. Geog. Bull. 20: 39-57. 1963.

McDonald, B. K. Growing cereal crops in Central British Columbia. Can. Dept. of Agr. Pub. 1165. 1963.

McDonald, B. K. Climate and agriculture in Central British Columbia. Can. Dept. of Agr. Pub. 1190. 1964.

McKay, G. A. A detailed map of Prairie average annual precipitation. Met. Branch, Can. Dept. Transport, Toronto, Ont. 1961.

Penman, H. L. Natural evaporation from open water, bare soil and grass. Proc. Roy. Soc. (London) A193: 120-145. 1948.

Putnam, D. F. The climate of the Maritime Provinces. Can. Geog. J. 21: 134-147. 1940.

Spence, C. C. and E. C. Hope. An economic classification of land in fifty-six municipal divisions in south central Saskatchewan. Tech. Bull. No. 36, Can. Dept. Agr., Ottawa, 1941.

Thomas, M. K. Snowfall in Canada. Circ. 3977, Tec. 503. Met. Br., Can. Dept. of Transport, Toronto, Ont. 1964.

U.S.D.A. Plant hardiness zone map. Misc. Pub. No. 814, Washington, D.C. 1960.

Villeneuve, G. O. Climatic conditions of the Province of Quebec and their relationship to the forests. Met. Br., Dept. Lands and Forests, P.Q., Bull. No. 6, Quebec, 1946.